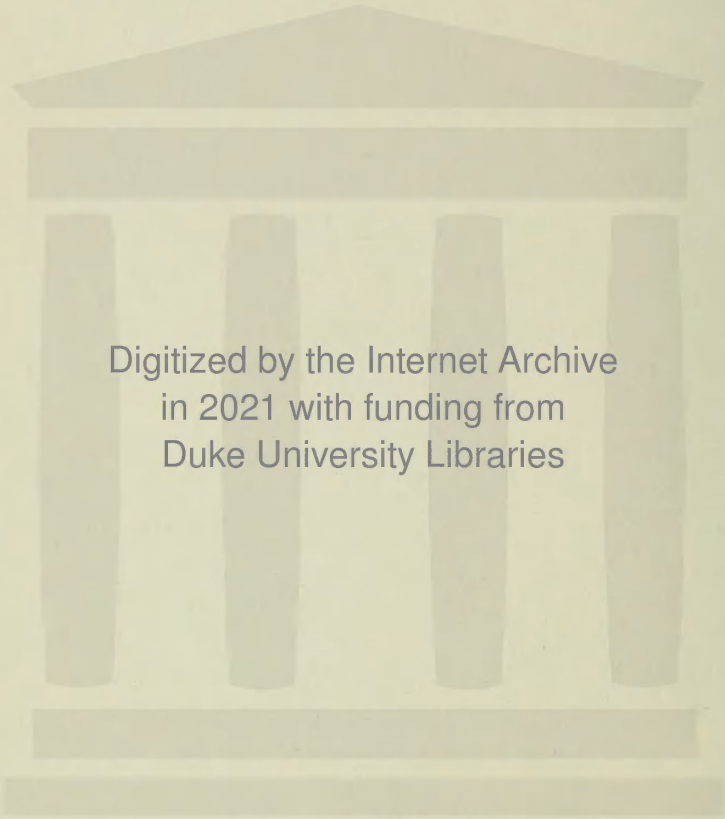
A LABORATORY MANUAL OF GENERAL BOTANY

BLOMQUIST AND WILKERSON



DUKE UNIVERSITY PUBLICATIONS

A LABORATORY MANUAL OF GENERAL BOTANY

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BY

HUGO LEANDER BLOMQUIST

Professor of Botany in Duke University

AND

NUMA FRANCIS WILKERSON

Instructor in Botany in Duke University

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PREFACE

It is a fact, quite generally recognized, that no manual of botany, regardless of its merits, has ever been written which suits every instructor or is applicable to every method of teaching or organization of the course or to every institution or locality. The principal reason for this lies in the nature of the laboratory material. While there is a more or less conventional method of presenting the subject in the lectures, there is no science in which the laboratory material may be varied so much as it may in the study of plant structures and plant life. It is fortunate that this is so, since fresh material should be used as much as possible, and considerable time should be devoted to field work.

Since no manual has so far been found entirely suitable for the course in general botany as it is given at Duke University, this one was prepared. Its purpose is to aid the instructors and to guide the students in the laboratory and in the field. The authors have taught this course for six consecutive years in the same institution and have used the material and methods here published both in multigraph sheets and in printed loose-leaf notebook form. During that time the authors have made a special study of the organization, methods, and materials employed in the laboratory work, and many revisions and changes have been made.

The selection of material and its arrangement are original in so far as a laboratory manual may be said to be original, although helpful suggestions have been obtained from such manuals as Transeau and Sampson's, Densmore's, and Holman's. Several different textbooks have been used with this manual, and the experience has been that it may be used with equal success with any good modern text.

The authors wish to express their appreciation to the editors and to Dr. Bert Cunningham for many helpful suggestions and to the Bausch & Lomb Optical Company for permission to use Figure 1 taken from their booklet, *Use and Care of the Microscope*.

H. L. Blomquist
N. F. Wilkerson

Duke University,
April 15, 1926.

A LABORATORY MANUAL OF GENERAL BOTANY

PRELIMINARY INSTRUCTIONS

LABORATORY STUDY

In the biological sciences the laboratory method of study has proved itself to be the most successful method. The reason for this is that when one sees a thing with his own eyes he forms a definite image of it and consequently understands and retains it much better than if he simply reads about it. Huxley, one of the greatest teachers of biology that ever lived, once said, ". . . all language is merely symbolical of the things of which it treats: the more complicated the things are, the more is the symbol, and the more its verbal definition requires to be supplemented by the information derived directly from the handling, and the seeing, and the touching of the things symbolized." Another great teacher of biology, Louis Agassiz, gave expression to the same idea when he said, "Study Nature, not books." These men did not mean, of course, that books should be entirely discarded from biology courses; their great emphasis upon laboratory study was due to the fact that they were living in an age when the laboratory was an innovation in the institutions of learning.

The laboratory method does not mean that the plants and animals should necessarily be studied indoors; the point is simply that the information is obtained first-hand by seeing and by studying, experimenting, drawing, describing, and interpreting what one sees. Indoor study has probably been over-done. In earlier times the laboratory of students of animals and plant life was mostly the out-of-doors, walled in by the horizon or the limit of vision and roofed by the dome of the blue sky. But of course their aim was different from that of students of today. They were primarily concerned with the mode of living, or natural history, and classification of the plants and animals, and the only necessary equipment was a magnifying glass. Because of the tremendous development of the subjects of morphology, or the study of structure, and physiology and the subdivisions of these subjects since the middle of the last century, it has become necessary to have an indoor laboratory as a place where the necessary equipment is housed and where it may be most effi-

ciently used. While much of the study must be done in this laboratory, it should be supplemented as much as possible by outdoor or field work.

A student who has had no experience in laboratory study is more or less confused when he enters a laboratory for the first time. He seems utterly helpless and at loss as to what to do. A few remarks about what to do and how to act in the laboratory may therefore be helpful. One of the first things to do in the laboratory is to learn to observe. This is one of the most essential things in all laboratory study; power of keen and critical observation is an important part of a good biological training. A second point is the cultivation of a proper mental attitude. Looking at an object and drawing it is of little value unless one does it with an inquiring mind. Ask yourself questions continually. What am I trying to do? What am I looking at? How does this organism or this structure differ from those studied before? What are these structures for? What does it all mean? Study the things you are looking at as if you were the first person to see them. Remember, the organism or the structure you are looking at very probably never was seen by human eyes before. This mental attitude has brought forth many startling discoveries in the past and will no doubt do the same in the future.

Be industrious; be persistent; strive for improvement in your work. Work independently. Make use of your time in the laboratory. It is an invaluable opportunity. Do not hurry, but be thorough. Be sociable, but not to an extent that it interferes with your own work or with that of another.

THE USE OF THE MICROSCOPE

The compound microscope is an instrument which deserves the highest admiration, wonder, and respect of everybody. For one thing, it has taken the labor of some of the best minds in several centuries to bring it to its present state of perfection. Again, the use of this instrument has led to many important discoveries vital in bringing to pass our present high state of civilization. It is useless to enumerate these discoveries here, because only an advanced student of biology and its history can fully appreciate them.

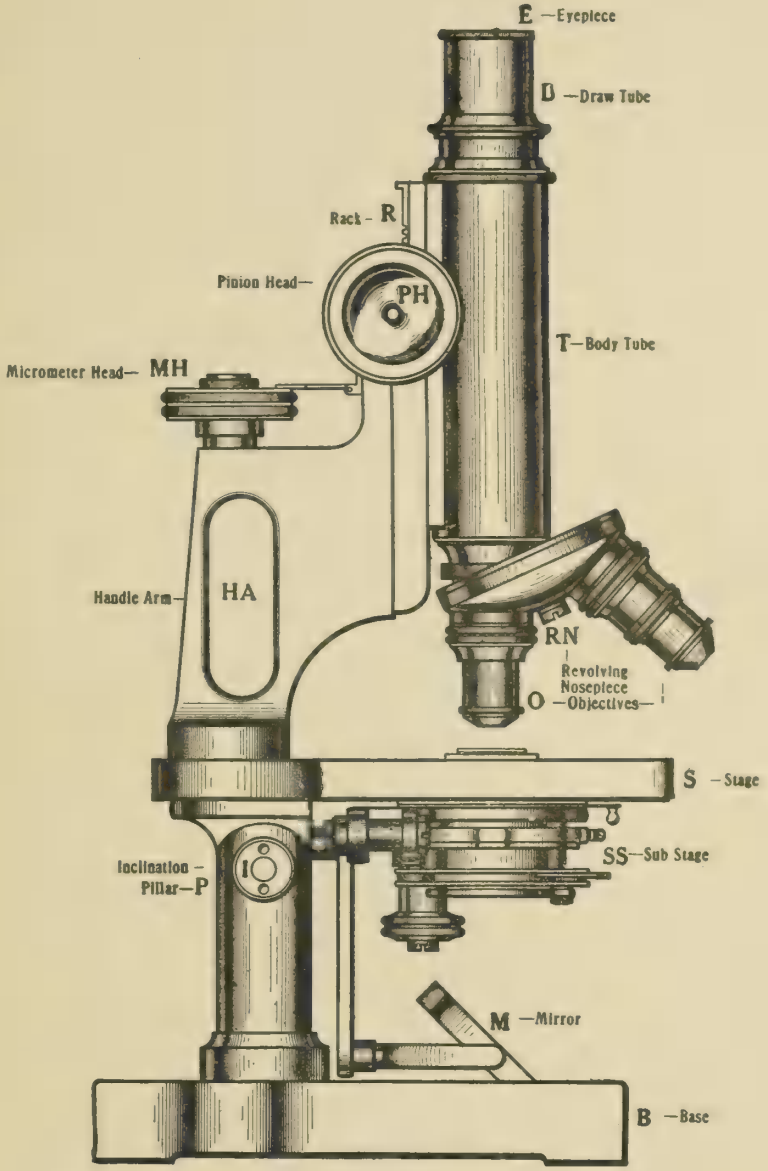
E —Eyepiece
D —Draw Tube
Rack - R
Pinion Head—
PH
T—Body Tube
Micrometer Head— MH
Handle Arm—
HA
RN
Revolving
Nosepiece
O —Objectives—
S —Stage
SS—Sub Stage
Inclination —
Pillar—P
M —Mirror
B —Base

FIGURE 1

Some of the first things to learn in the use of the microscope are, how it is made, upon what principles it is based, and the names of its different parts. The instructor will tell you these things, but a study of Figure 1, which is a diagramatic drawing with the different parts labeled, will help you to remember them.

An important thing to be observed is the correct position of the microscope with reference to the student and of the student with reference to the microscope. The chair of the student should be high enough so that he can look into the microscope comfortably without breaking it at the joint. The advantages of the upright position of the microscope are that better light is secured and, if one is examining a drop of liquid, it will not run off the slide. Since students are of various sizes, an adjustable chair is necessary. The handle arm of the microscope should face the student.

The second matter of importance is the location of the light. Looking in the microscope with your right eye, take hold of the mirror with the left hand, if the light is from the right, or with the right hand, if the light comes from the left. Face the mirror towards the light at an angle of about forty-five degrees so that the light is reflected upward through the opening in the stage. The microscope has a concave and a plane mirror. Students are sometimes confused as to which mirror to use, and this should, therefore, be cleared up at once. Use the concave mirror when the source of light is near, as when using artificial light, and when no condenser is used. For daylight it is better at all times to use the plane mirror. Always be sure that you have obtained the best light possible. For high-power magnifications, success depends upon having good light.

See to it that the ocular and objective lenses are clean and that the microscope is in perfect focus. Do not be satisfied until the object is perfectly clear and distinct. Clean lenses and perfect focus will give this result. Always use the low power first; do not use the high power unless necessary. In searching for an object, always use the low power. If you can not find it with the low power, you surely can not find it with the high. In changing from low to high power, the object must be in the center of the field, otherwise you will have difficulty in finding it. While look-

ing in the microscope, never focus down very far, especially when using the coarse adjustment; because, if you do, you will sooner or later break the slide.

Place the slide on the stage so that the object you wish to examine is as near the center of the opening of the stage as possible. Using the low power (the shorter objective), turn down the tube until the objective is about an eighth of an inch from the slide. Then, looking into the microscope, raise the tube with the coarse adjustment until something is seen. Now use the fine adjustment for getting a sharper focus by turning it up and down or to right and left, as the case may be, depending upon the make of the microscope. In using the high power (the longer objective), the objective must be lowered until it is so close to the slide that you can just barely slide a thin paper between. Then, looking into the microscope, proceed as with low power. Remember, it is much more difficult to use the high power than the low. At the end of the period, straighten up the microscope, raise the tube slightly, and leave it in low power. Be very careful not to turn the tube down so far that the objective goes through the opening in the stage. This will break the diaphragm if it is not opened wide.

INTERPRETATION OF MICROSCOPICAL IMAGES

Most objects look flat in the microscope. Very few of them are. Train yourself to see in three dimensions. In order to get the proper perspective, the object must be studied at different levels. With the fine adjustment, focus on the upper, middle, and lower levels. For objects larger than the field of the microscope, the slide must be moved. This is rather difficult, since the movements are also magnified, and the object is reversed. If you wish to move the image to the right, move the slide to the left, and *vice versa*.

SLIDES AND COVER GLASSES

Good laboratory work includes a minimum amount of breakage of slides and coverglasses. Be especially careful with prepared slides. Some of them are invaluable. Be careful in cleaning coverglasses. There is no excuse for breaking slides and coverglasses with the objectives.

DRAWING

"I can't draw", "I never could draw", or "I simply cannot learn to draw", are some of the expressions a teacher of biology hears from his elementary students when he enters the laboratory for the first period of their work. The students do not seem to realize that the teacher has heard this before, and the only thing for the teacher to do is to smile and say, "Oh, yes, you can", "We'll teach you how", or "Well, you do not have to be an artist to study biology". A student might more profitably say, "I have never been able to draw, but I wish I could draw, and I'll try my best to learn how." The statements above attributed to the teacher are essentially true; everybody is able to draw more or less and can be taught how if he is willing to try, and anyone who takes pains is able to draw well enough to make a good record in biology.

What we are and especially our manner of doing things depend largely upon our attitude of mind. Since drawing is an attempt to represent what one sees, one must constantly bear in mind that it must be drawn as it is. This attitude of mind is especially necessary in biological drawing, because, above all, this type of drawing must be accurate. A student who tries to follow this suggestion will no doubt make some ludicrous mistakes at first, but, as he becomes better able to use the microscope and interpret what he sees, his mistakes will gradually be reduced. Later on, a little "idealizing" of the drawing may be permissible.

There are two kinds of drawings in biology: microscopical and macroscopical, or sketching. The two types require a different technique. Success in the first type of drawing depends largely upon ability to use the miscroscope and to interpret what is seen.

When you look at an object in the microscope, it generally looks flat, but very few things are flat. They appear so because you are using only one eye, and the focus of the microscope lies in a thin plane. Learn to see things in three dimensions in the microscope as elsewhere. Focusing the microscope upon the upper, middle, and lower regions of the object will help you to do this.

Very few instructors in biology are artists, and those who are probably will not attempt to teach art. They can, however, give their students some very helpful suggestions which, if observed, will improve their drawings very much.

One of the first things to learn in microscopical drawing is how to draw a line, not a straight line necessarily, but just a line. Examine the two lines in *Figure 2* and decide which is the better.

FIGURE 2

Why is one better? Because it is of the same width throughout. A line can be drawn so by holding the pen or pencil in the same position while drawing it and bearing down evenly. Do not twist the pencil while drawing a line. If all lines have the same width throughout their whole length, the appearance of your drawing is improved surprisingly.

FIGURE 3

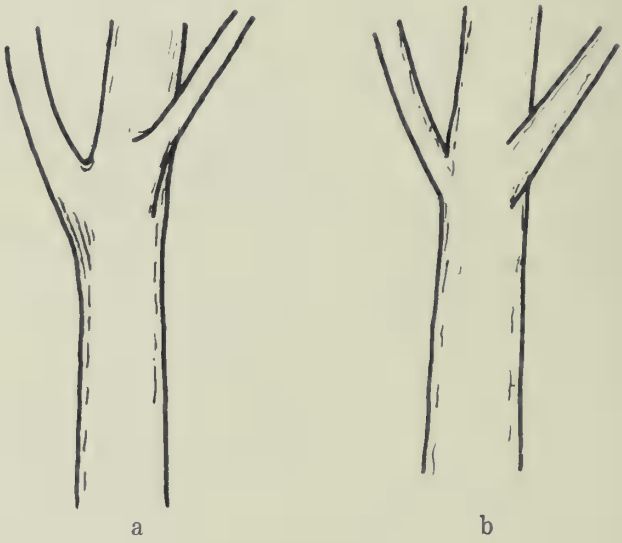

FIGURE 4

The next point deals with the drawing of two lines. Examine *a* and *b* in *Figure 3*. Which is more pleasing? You notice, of course, that the drawing that makes the better appearance has the two lines parallel. It is surprising how many things in nature have parallel lines, and if the lines are parallel they should be drawn so.

A third point to be observed in drawing is illustrated in *a* and *b*, *Figure 4*. It will not take you long to decide which is the more pleasing. Why? Have you noticed how few things in nature have sharp corners and absolutely straight lines? This point applies, however, more to habit sketches than to microscopical drawings.

In microscopical drawing use sharp, bold lines. Shade as little as possible, but, if shading is necessary, use stippling *(Figure 5)*.

In habit sketching it is well to remember that sharp angles and corners should be avoided. Shading the object evenly makes it look flat, when, in reality, very few things in nature are perfectly flat.

FIGURE 5

NOTES

Make your notes brief, but explicit. Write down the things which are most important. At first this is difficult to determine, but you will soon learn what is important and what is not. First of all, state in your notes what you have done in the laboratory,

including the purpose of the work, the materials, methods, observations, etc. If you are working with any particular plant, add a short discussion of its structure and form, habitat, distribution, method of reproduction, and any special peculiarity, its life history, and its economic importance, if any. Be sure to include a diagram of the plant's life history. This information you will get from various sources: lectures, textbooks, reference books, talks by the laboratory instructor, and your own observations.

PART ONE

OUTLINE OF PART I

I. THE UNIT OF STRUCTURE: THE CELL

1. The Cell Wall
2. The Cell Structure
3. The Living Plant Cell

II. THALLOPHYTES

1. The Algae

a. Cyanophyceae (the blue green algae)

(1) Oscillatoria
(2) Nostoc
(3) Cylindrospermum

b. Chlorophyceae (the green algae)

(1) Protococcus
(2) Chlamydomonas or Sphaerella and Volvox
(3) Desmids
(4) Diatoms
(5) Spirogyra, etc.
(6) Ulothrix, etc.
(7) Oedogonium
(8) Vaucheria

c. Phaeophyceae (the brown algae)

(1) Ectocarpus, etc.
(2) Fucus, etc.
(3) Padina

d. Rhodophyceae (the red algae)

(1) Nemalion
(2) Polysiphonia

2. The Fungi

a. Schizomycetes (bacteria)

b. Phycomycetes

(1) Saprolegnia (water mould)
(2) Mucor (bread mould)

c. *Ascomycetes*
   (1) Yeast
   (2) Peziza and Morchella
   (3) Aspergillus and Penicillium
   (4) Lichens

d. *Basidiomycetes*
   (1) Mushrooms, puffballs, etc.

e. *Protobasidiomycetes*
   (2) Ustilaginales (smuts)
   (3) Uredinales (rusts)

III. BRYOPHYTES

1. Hepaticae (Liverworts)

   a. *Riccia*
   b. *Marchantia*
   c. *Anthoceros*

2. Musci (Mosses)

   a. *Sphagnales (peat moss)*
   b. *Bryales (true moss)*

IV. PTERIDOPHYTES

1. Filicales (True Ferns)
2. Lycopodiales (Club Mosses)

   a. *Lycopodium*
   b. *Selaginella*

V. FIELD STUDY

EXERCISE 1

I. THE UNIT OF STRUCTURE: THE CELL

The Cell Wall. Obtain a prepared slide of a cross section of a stem. Place this on the microscope stage with the side having the coverglass upward, so that the section is in the center of the opening of the stage or directly below the objective. Using the low power (the shorter objective), with the coarse adjustment, turn the microscope tube down until the objective is about a quarter of an inch from the slide. Then, looking in the microscope, raise the tube until something is seen. Using the fine adjustment, raise or lower the tube until the object is perfectly distinct. Move the slide to determine if the compartments are all alike. Select a place in the section where the compartments have thick walls, and draw a few as accurately as possible. Now raise the tube and swing in the high power objective. Lower the tube until it almost touches the slide. Again, looking in the microscope, raise the tube until something is seen, and adjust the focus with the fine adjustment. Study the walls of the compartments and draw a few. Are the walls double or single? Why?

The Cell Structure. From the instructor obtain a prepared slide of a section of a root tip or of some other growing part of a plant. Proceed as before, using the low power first. What are the differences between these cells and those studied in the stem? Where does the cell wall come from? Of what substance is it composed? Using the high power, draw a few cells as accurately as possible.

The Living Plant Cell. Secure a part of a living plant. A moss leaf will do. Place it in a drop of water on a slide and cover with a coverglass. Study with low and high power. Draw a few cells under high power. Is the green color distributed uniformly throughout the cell? What is it called? What are the bodies containing the green color called? Do you see any other particles in the cell? What are they called? What is the transparent jelly-like substance in the cell called?

REFERENCE

Sharp, L. W., *An Introduction to Cytology.*

EXERCISE 2

II. THALLOPHYTES

1. Algae

a. Cyanophyceae (the blue green algae)

Oscillatoria. Examine the material with the naked eye. Touch it with a needle. Note the color and the structure of the colony. Place a small piece of the material on a slide in water and cover it with a coverglass. Examine with low and high power. Is it made up of one or of many cells? If many, how are the cells arranged? What is the shape of the cells in the thread? What is the shape of the cell at the tip? Why? Examine the thread carefully and determine if all cells are alike. You should find some which are empty. These are called *heterocysts.* What important part do they play in the life of the plant? Does the plant move? Determine the kinds of movements. Draw carefully a few filaments as seen under low power. Draw a part of one filament under high power, including the end cell and a heterocyst. Plants with this cell arrangement are called filamentous.

Nostoc. Examine and draw colonies of Nostoc. How do these colonies differ from those of *Oscillatoria?* Where does the gelatinous substance come from? What is it for? What part does it play in the geographical distribution of these plants? Mash a small piece of the colony on a slide in a drop of water and examine under high power. Draw accurately a complete individual. Where are the heterocysts and how do they differ from those in *Oscillatoria?*

Cylindrospermum. Study this plant in the same manner as those above. Note the differences and resemblances.

REFERENCES

West, G. S., *Algae*, I; Wolle, F., *Fresh Water Algae of the United States.*

EXERCISE 3

II. THALLOPHYTES

1. Algae

b. Chlorophyceae (the green algae)

Protococcus. This minute plant occurs on the shady side of trees, fences, and buildings, forming a characteristic green coving, which is especially evident in damp or rainy weather. Examine with the naked eye a piece of bark having this plant on it. With a knife or a needle carefully scrape off a little of the green substance on a slide in a drop of water, being careful to get as little of the bark as possible with it. Cover with coverglass and examine with low and high power. What is the shape of the plant? Is it a one-celled or a multicellular individual? How do you know? Is it motile? How does this plant reproduce? Look for a single plant and draw it carefully under high power. Notice the following parts: cell wall, *chloroplast*, *nucleus*. If you have difficulty in seeing the nucleus, add a drop of eosin on the side of the coverglass and draw it under with a blotter. Make drawings of at least four stages in the reproduction of this plant.

Protococcus is supposed to be the simplest of all plants. What does this mean? It does not necessarily mean that it is the most "primitive". What is your conception of the most primitive plant? Why?

This plant belongs to a group of plants characterized by non-motile vegetative cells. The reproductive cells, if any, may, however, be motile. Other forms in this group are: *Scenedesmus*, *Pediastrum*, and "Water-Net" or *Hydrodictyon*. If available, examine these and make habit sketches.

REFERENCE

Coulter, J. M., Barnes, C. R., and Cowles, H. C., *Textbook of Botany*, I.

EXERCISE 4

II. THALLOPHYTES

1. Algae

b. Chlorophyceae (Continued)

Sphaerella. This microscopial plant occurs frequently in depressions in pure limestone rocks or marble. It is most easily collected from depressions in marble monuments or tombstones. When dry, it appears as an encrusted red layer.

In some regions, especially in colder climates, it grows on ice and snow and has been named "red snow". In order to get the most desirable stages of this material, it is best to scrape off some of the encrustations and put them in rain or pond water in the evening. The following morning the material should be in the best condition, which means that almost all stages in the life history of this plant are represented.

Put a drop of the liquid on a slide and cover with a coverglass. Examine with low power and try to locate the small moving bodies. Since this is a motile plant it is rather difficult to study. After finding it with high power and after having determined its motility, put a small amount of iodine on the side of the coverglass. This will make it more easily seen and studied, because it will remain stationary and will be slightly colored.

Make drawings of the vegetative cell showing *cilia*, the *transparent sheath*, *the protoplast* with its "eye spot". What is this red spot supposed to be for? Search for those which are dividing into smaller ones. What kind of reproduction is this? How does this method differ from the method in *Protococcus?*

In the material, you should also find spherical cells with a thick wall and colored red. This is called the encysted stage and is the condition the plant assumes under unfavorable conditions such as drought, heat, the presence of unfavorable substances, etc.

Volvox. This is a good example of what is called a colonial form. All the cells making up this plant resemble *Sphaerella.* Make a drawing of the plant showing form, individual cells, and the young colonies inside of the sphere. How does this plant reproduce? Does it show specialization?

REFERENCES

West, *Algae*, I; Wolle, *Fresh Water Algae of the United States;* Coulter, Barnes, and Cowles, *Textbook of Botany*, I.

EXERCISE 5

II. THALLOPHYTES

1. Algae

b. Chlorophyceae (Continued)

Desmids. These are fresh water unicellular forms which, because of their sexual reproduction, resembling that of *Spirogyra*, belong to the same group called the Conjugales. With a pipette, put a drop of water containing desmids on a slide and cover with a coverglass. Examine with low power. Notice the oblong and more or less curved shape. Notice also that the cell seems to be divided into two equal halves. Study them under high power. Notice the large green chloroplast in each half. Notice also the *pyrenoids* on this. Try to determine the shape of the chloroplast. Look for the nucleus in the center of the cell. Examine the end of the plant Notice the clear globule with the small bodies in motion. Make an accurate drawing of one desmid. If the material is abundant, you should find stages of cell division. Draw as many of these stages as you find, including a newly formed desmid. If material is available, draw *conjugation*, *zygospore*, and other desmids.

Diatoms. These are unicellular plants which occur in both fresh and marine waters. They are not closely related to desmids, but are included here because they are usually found with them and have the same method of sexual reproduction. Notice the rectangular shape. This is the side view. Under high power, draw carefully this view showing the lines which are the edges of the two halves of the wall, which come together like two halves of a pill box. Try to find one turned so that it has a more oblong shape. This is called the valve side, while the former is called the girdle side. What is the coloring matter in these plants? Do they move? If so, how? Since the cell walls are made of very hard substance, the protoplast is not able to break them. How does it reproduce by cell division? Draw stages showing cell division. In this mode of cell division what peculiar result is obtained? Does this plant have sexual reproduction? Examine diatomaceous earth and draw as many different forms of shells as you can find. This earth is simply an accumulation of shells of diatoms that lived ages ago. It is sometimes used as a cleaning powder.

REFERENCES

West, *Algae*, I; Wolle, F., *Desmids of the United States;* William, H., *Fresh Water Algae of Connecticut;* Mann, A., *Diatoms;* Wolle, F., *Diatomaceae of North America.*

EXERCISE 6

II. THALLOPHYTES

1. Algae

b. Chlorophyceae (Continued)

Spirogyra. This is a floating form which occurs in fresh water pools and ponds. If possible, examine it in its natural habitat. Examine it close with the naked eye and with a magnifying glass. Leave some of it in the sun for an hour and examine again. Compare this with some which has been left in the dark. What difference do you observe? What causes the bubbles of gas to appear? What is this gas? Put some of the filaments under low power and examine. Why is it called *Spirogyra?* What are the green spiral bands? What are the "buttons" on this band? Note the nucleus in the center of the cell suspended by strings of *cytoplasm*. Examine under high power, and draw accurately one cell showing all the parts of the cell. From living, preserved material or prepared slides, study reproduction. Select first a stage in which the dark round or oval bodies are fully formed. Notice that these are found in one of two filaments which are united by tubes in parallel. What do you suppose has taken place? What are the dark bodies called? Study and draw as many stages as you can find in the formation of the zygospore. The union of two cells is called conjugation. This is a form of *fertilization* and is the essential fact which makes reproduction sexual. Each cell is then called a *gamete*. When the gametes look alike, we call the reproduction *isogamous;* when unlike, *heterogamous*. Which is this? What part of the cell acts as a gamete in Spirogyra? Are the gametes exactly alike? If all the protoplasts from one filament go into another, what does this probably mean? Does *Spirogyra* reproduce asexually?

Other plants closely related to *Spirogyra* are *Zygnema*, *Zygogonium*, and *Mougeotia*. The second one is like the first, except that the zygospores are formed in the tube between the filaments. Examine and make sketches of these if available.

REFERENCES

West, *Algae*, I; Wolle, *Fresh Water Algae of the United States*.

EXERCISE 7

II. THALLOPHYTES

1. Algae

b. Chlorophyceae (Continued)

Ulothrix. Examine fresh or preserved material with the naked eye. These plants occur attached on rocks on the edges of lakes and in streams or where the water is in constant motion. Mount a small portion of the material in water on a slide; cover with a coverglass, and examine as before. What kind of a plant is this one? What is the shape of the chloroplast? This is an attached form. How is it attached? Make a careful drawing of the filament showing the *holdfast* cell. This plant shows in the holdfast cell specialization and some differentiation. What do these terms mean? If you have living material, study *zoöspore* formation and their germination. What is a *spore?* A zoöspore? Sometimes two of these cells fuse, acting as gametes, and sexual reproduction takes place. What are gametes, and what is sexual reproduction? From prepared slides draw a few cells, under high power, showing zoöspore or gamete formation.

Cladophora. How does this form differ from *Ulothrix?* Note especially the branching habit and number of nuclei in each cell. This is said to be partly *coenocytic.* What does this mean? Make a drawing of a part of the plant, including the tip, showing the mode of branching and nuclei.

Other forms in this group are: *Ulva* or sea lettuce (a marine form), *Chaetophora*, and *Stigeoclonium*. If available, and you have time, make sketches of these.

REFERENCES

West, *Algae*, I; Collins, F. S., *The Green Algae of North America.*

EXERCISE 8

II. THALLOPHYTES

1. Algae

b. Chlorophyceae (Continued)

Oedogonium. This is an unbranching, filamentous form usually found in stagnant or slightly moving fresh water. The peculiar things about this plant are, its method of growth and its method of sexual reproduction. Examine fresh material if available and notice the shape of the cells and the chloroplast. This chloroplast is said to be reticulate. On some cells you will notice rings on one end. These are the edges formed when the cells divide. The instructor will explain this mode of division. Draw carefully a cell of this plant. Draw also a cell having the "rings of growth". From preserved material study sexual reproduction. In this plant the gametes are different (heterogamy). This means that the sex cells have become highly specialized and differentiated. The female gamete is called the *egg*, and the male gamete the *sperm*. Both may occur in the same filament (monoecious) or in separate filaments (dioecious). The cell which includes the egg is called the *oögonium*, while the cell which contains the sperms (two in this case) is called the *spermogonium* or *antheridium*. The difference in the gametes is in the size and motility. The egg is large and stationary, while the sperm is small and motile. Draw an oögonium showing the thick wall and the egg and the opening where the sperm entered. This has been fertilized and is therefore an *oöspore*. An oöspore is simply, then, a special zygospore. Either may be called a *zygote*. Look for antheridia and draw, showing the number of sperms in each cell.

Asexual reproduction is brought about by large zoöspores. These resemble eggs, except that they are motile, having a crown of cilia at one end just like the sperms. When the oöspore germinates, it produces four zoöspores, which give rise to new plants. If material is available, study young plants which have come from zoöspores and draw. Note the holdfast cell. What is its function? What relation does it have to habitat?

REFERENCES

West, *Algae*, I; Collins, *The Green Algae of North America;* Coulter, J. M., *Evolution of Sex in Plants.*

EXERCISE 9

II. THALLOPHYTES

1. Algae

b. Chlorophyceae (Continued)

Vaucheria. This is often called "green felt" because of its dark green felt-like appearance when seen on the edge of streams, on the bottom of ponds and streams, or sometimes floating. Examine some living material with the naked eye and with a magnifying glass. Can you make out the shape of the plant with the naked eye or with the magnifying glass? This is one of the largest of fresh-water algae. Examine some under low power and draw a piece showing branching. Do you find any cross cell walls? What is such a plant called? Study the inside of the tube and draw a piece of it showing chloroplasts, fat globules, and nuclei. If the latter are hard to find, examine a prepared slide. Examine some material which has been submerged in water over night. Notice the large swellings. These are the zoöspores. Search for some of these bodies which are germinating and draw. These zoöspores have many nuclei and many cilia.

From the proper material, study sexual reproduction. Look for dark green oval shaped organs. These are the oögonia. Near them you should find the antheridia. Draw these two organs very carefully. Notice that the walls have formed below the oögonium and across the antheridium.

In some forms there are many oögonia around one antheridium, all terminating a special branch. The oöspore germinates into a new plant directly.

A closely related plant to this one, as small green spheres about the size of a pin head, is often seen on moist ground near streams. This is called *Botrydium*. If material is available, examine and draw one.

REFERENCES

West, *Algae*, I; Collins, *The Green Algae of North America*.

EXERCISE 10

II. THALLOPHYTES

1. Algae

c. Phaeophyceae (the brown algae)

The brown algae are almost all marine. They occur on all seacoasts, but are more abundant in the cooler waters. Most of them are large thallose plants, some of which reach large dimensions.

Ectocarpus. Put some of the preserved material on a slide and examine under low power. What plant of the green algae does it most resemble? Make a habit sketch of part of the plant, including the tips of the branches. Note where the branches come off. Note also the dark, dense bodies. Are they made up of one or of many cells? These are the *gametangia*. What do they produce? Is this plant isogamous or heterogamous? Make a careful study of the development of these organs. Make drawings of at least five stages, including the youngest you can recognize as a gametangium and the oldest. This plant has also *sporangia*. If material is available, study and draw these also.

Examine herbarium specimens of other brown algae belonging to this group. Make habit sketches of *Laminaria*, *Macrocystis*, and others. These forms are isogamous and are therefore classed together in the order Phaeosporales.

REFERENCES

Coulter, Barnes and Cowles, *Textbook of Botany*, I; Arnold, A. F., *The Sea-Beach at Ebb-Tide*.

EXERCISE 11

II. THALLOPHYTES

1. Algae

c. Phaeophyceae (Continued)

Fucus. Make a macroscopical examination of this plant. Note the holdfast organ (the rhizoids), the *stipe*, and the long branching lamina or blade. Note the peculiar branching. This is called *dichotomous*. Note also the swellings on the blade and at the tips of some of the branches. These swellings are of two kinds; those at the tips hold the reproductive organs and are called *receptacles;* those on the blades lower down are simply air bladders, or floats, which help to hold the plant up in water. These plants are marine, occuring in the tidewater zone on rocky shores in the cooler waters. Make a good habit sketch of the whole plant, including the *rhizoids*, stipe, blades, floats, and receptacles. From prepared slides, make a diagram of a cross section of the receptacle showing the pits or *conceptacles*. The receptacles are either male or female. Under low power make a diagram of the male conceptacle showing the *paraphyses* and antheridial branches. Make, likewise, drawings of the female conceptacles showing oögonia and paraphyses. Under high power, draw an antheridium showing sperms and an oögonium showing eggs.

If living material is available, observe the demonstration of fertilization in this plant and make a sketch of it.

Sargassum. Sargassum is a form which resembles *Fucus*, except that it is usually found floating in the ocean, especially in the Caribbean sea (Sea of Sargasso), after which the plant is named, and the Gulf Stream. Make a sketch of it.

REFERENCES

Coulter, Barnes and Cowles, *Textbook of Botany,* I; Arnold, *The Sea-Beach at Ebb-Tide.*

EXERCISE 12

II. THALLOPHYTES

1. Algae

c. Phaeophyceae (Continued)

Padina. Make a study of this plant from preserved material or from herbarium sheets. Notice that there are three plants on each sheet. Do you see any essential differences between them? Although they may look alike, microscopical examination shows that they are all different. Make a habit sketch of one of them. Also examine preserved material. This plant is a marine form, whose life history has been worked out recently and it is therefore not usually discussed in the textbooks. Its life history, however, resembles *Dictyota*, which is discussed in the more advanced books. From the instructor, secure pieces of the preserved material. Place these on the slide in a drop of water. In the study of the whole plant, you should have noticed dark lines or zones. These are where the reproductive organs occur. Make sketches of the antheridia, oögonia, and sporangia under high power.

Why does this plant appear in three different kinds? The explanation is this: This plant illustrates a thing very common in the higher plants, known as "alternation of generations". That means that there are two generations in the life history of this plant, alternating with each other. One of the generations is sexual, and the other is asexual. Consequently, we find two kinds of plants, the sexual and the asexual. But it happens that in this plant the male and female gametes are produced on separate plants, hence there are three kinds. When the egg is fertilized, it does not develop into male or female plants, but develops into a plant which has no sex. This plant does not produce antheridia and oögonia, but sporangia. When the spores germinate, they produce male and female plants, and the life history is completed. What resemblances does this plant show to *Oedogonium?* Just how do the two differ in their life histories? Would you conclude that *Oedogonium* has alternation of generations?

REFERENCES

Wolfe, J. J., "Alternation and Parthenogenesis in Padina," *Journal of Elisha Mitchell Scientific Society*, XXIV. 78-109. (1918); Strassburger, E., *Textbook of Botany*, (5th Ed.).

EXERCISE 13

II. THALLOPHYTES

1. Algae

d. Rhodophyceae (the red algae)

These plants are almost all marine, occurring in the warmer waters and at greater depths than the browns. Most of them have a red color in addition to the chlorophyll, which is entirely masked. While red color is common to the majority of these plants, and most of them live in the sea, there are some which are green and live in fresh water. The best distinguishing characteristic is the reproduction, which is extremely complex.

Nemalion. This is one of the simpler of the red algae. Study prepared slides. Note whether it is simple or branching, filamentous or thallose. Study the tips especially. Make a drawing showing the method of branching. Also make drawings showing antheridia, *procarp* with *carpogonium* and *trichogyne*, and *cystocarp* with *carpospores*.

Polysiphonia. Make a sketch of this plant from herbarium sheets. Note the branching habit and rhizoids or holdfast. Mount some of the preserved material on a slide and examine. Is it filamentous or thallose? How does it branch? Why is it called *Polysiphonia?* How many plants are there in the life history? Does it have alternation of generation? Make a drawing of a male plant, including the tip so as to show antheridia, a female plant showing procarp, a female plant showing cystocarp and carpospores, a *tetraspore* plant *(sporophyte)* showing *tetrads*.

REFERENCE

Coulter, Barnes and Cowles, *Textbook of Botany*, I.

EXERCISE 14

II. THALLOPHYTES

2. Fungi

a. Bacteria

Expose agar plates to air for one or two hours. Leave one plate unexposed. These plates are sterile, which means that there is not a single living organism in them before they are exposed. After they are left in the incubator at thirty-seven degrees Centigrade (ninety-eight degrees F) until the next period, examine them again. Notice the spots formed. These are colonies of bacteria composed of millions of organisms. Count the total number of different colonies and the number of each kind. Make a sketch of each different colony. Study the different colonies and see how they differ. Make notes of this work.

With a needle, remove a small amount of a colony and stir in a drop of water on a dry slide. Cover with a coverglass and examine with a microscope. Can you see anything under low power? Do the bacteria move? Distinguish between Brownian movement and actual movement by the bacteria. How do bacteria move? Under high power, determine the shape and size of the individual organisms. Determine how they are grouped, whether in chains or in masses. Also examine a colony under low power. Can you make out the individual organisms? Examine the bacteria of several different colonies as above. Make notes and sketches.

From prepared slides, make drawings of the principal types of bacteria. If preparations showing cilia and spores are available, study and make sketches of these.

If slides of disease (pathogenic) bacteria are available, examine them.

REFERENCES

Marshall, C. E., *Microbiology;* Vallery-Radot, R., *Life of Pasteur.*

EXERCISE 15

II. THALLOPHYTES

2. Fungi

b. Phycomycetes

Saprolegnia. This fungus is usually called water mould, because it is found growing on insects or other bits of organic matter floating on water from ditches, ponds, and wells. It is seldom that one finds enough of it in nature to make a study of it. Consequently, the best thing to do is to grow it in the laboratory. The methods commonly used are as follows: Collect a number of insects, such as flies, bugs, etc., and throw them on water which has been collected from a ditch, pond, or stream. The water should be put in a flat dish, and it is better to cover it. After a day or two, you should find a cobweb growth on the insect. A better way is to boil some starchy corn, cut the grains up into small bits with a sterilized scalpel, and throw these into the water with sterile forceps.

Make a macroscopical study of the growth and sketch it. What type of plant is it? Place a whole growth in a small flat shallow dish in water and examine with low and high power. Notice whether the *hyphae* are septate. Make drawings of the hyphae. If you have the proper stage you should see sporangia. These are the walled-off ends of the filaments. Make drawings of a mature sporangium and an empty one. Are the spores motile or not? Draw some. This is the asexual method of reproduction and is the one which usually comes first. Sexual reproduction may be seen in the older growths. You should find oögonia with several eggs in them and antheridia near them. How is fertilization brought about in this plant? Make careful drawings of the sex organs. Which algae does this plant resemble from its method of reproduction?

REFERENCE

Coker, W. C., *Saprolegniaceae*.

II. THALLOPHYTES

EXERCISE 16

2. Fungi

b. Phycomycetes (Continued)

Mucor. This plant is commonly found on moist bread and is therefore usually called Bread Mould. It differs from bacteria and yeast in that it is filamentous and in this respect resembles some of the algae. To obtain *Mucor*, take a piece of bread and either leave in open air for several hours or throw it on the floor in places where considerable dust has accumulated. Then place it on some support above a dish of water and cover with a bell jar or something which is practically air tight. This will make a moist chamber. Then leave in a moderately warm place for a day or two.

If you have been successful, you should find the bread covered with a cobweb-like growth. Examine it carefully with the naked eye. Notice the color. What color substance does this lack which was found in the algae? What effect must this have upon its food relation? What kind of food does this plant use? Where did this food come from originally? How was this food prepared? Substances like these, which are produced by living organisms, are called organic. If the substance is used for food, it is called an organic food. Fungi like *Mucor*, which grow on dead organic substances, are called *saprophytes*, and this life relationship is called *saprophytism*. If possible, examine the plant with a magnifying glass. Notice the knob-like structures terminating the filaments. These are the sporangia. When they are mature, they are black. The filaments are collectively called the *mycelium*.

Place a small amount of the plant on a slide in a drop of weak solution of alcohol. Examine under low power. Do you see any cross walls in the filament? What is such a plant called? What plants in the algae does it resemble in this respect? Study the lower part of the plant. Notice the root-like structure which anchors the plant to the bread. This is called the *rhizoid*, because of its resemblance to a root. Notice the sporangium. Make a drawing of the plant showing the mature sporangium,

the filament, and the rhizoid. From a broken sporangium, obtain spores. Examine and draw. Also draw a sporangium. What is the *columella?*

Place some spores on the surface of a sugar solution in a covered petri dish and leave for twenty-four hours. Examine and draw germinating spores. Where are spores usually found in nature?

From prepared slides, make a study of sexual reproduction. Notice the large, dark bodies. These are the zygospores. Try to determine how they are formed and draw several stages in their formation, including the mature stage. If the zygospore germinates, what does it give rise to in this form? Is this plant differentiated into sexual individuals? What is meant by plus and minus strains? Why is it not possible to tell which is male and which female?

REFERENCE

Coulter, Barnes and Cowles, *Textbook of Botany*, I.

EXERCISE 17

II. THALLOPHYTES

2. Fungi

c. Ascomycetes

Yeast. Put a small piece of Fleishman's yeast in a flask containing grape juice or a solution of sugar. Mix well, stopper the flask with cotton, and leave in the incubator at thirty degrees Centigrade for twenty-four hours. Note the scum formed on top and the sediment on the bottom of the flask. Explain. Put a small amount of the sediment on a slide and examine under low and high power. What kind of an organism is yeast? Notice the method of reproduction. This is simple cell division, but it is called "budding". Under high power, draw a single organism showing the vacuole and nucleus. The nucleus can not be seen unless you add a drop of some coloring matter like eosin. Draw several stages in the production of new cells. Look for the different kinds of yeast. How do they differ? Make sketches of the different kinds.

Put some of the yeast solution in a wide-mouthed bottle, stopper, and leave for twenty-four hours. The stopper should have a funnel in it that can be closed and an outlet tube. Place the outlet tube in a solution of calcium hydroxide (lime water) or barium hydroxide. Pour water in the funnel. Open the funnel so that the water will drive out the air into the lime water. What happens? Explain. Blow air into some of the same solution. What happens? What is the resemblance between respiration and yeast fermentation? What are the two substances formed by yeast? From what are they formed? How does the yeast do it? What is the purpose of the process? In your notes explain the industrial uses of yeast and why it is used in these industries.

The fungi included in this group are characterized by a sporangium called an *ascus*. This structure resembles a sac, so the fungi are often called the sac fungi. The ascus is the walled-off end of a hypha slightly enlarged and contains a certain number of spores. These asci usually occur in a layer in some part of the plant together with some sterile hyphae, the *paraphyses*. This layer is called the *hymenium*. Since yeast very seldom produces this, it is not typical. We usually study as typical Ascomycetes, *Peziza* and *Morchella*.

REFERENCES

Marshall, *Microbiology;* Guilliermond, A., *The Yeasts* (Tr. by F. W. Tanner); Effront, J., *Enzymes and Their Application,* (Tr. by S. C. Prescott): Bayliss, W. M., *The Nature of Enzyme Action.*

EXERCISE 18

II. THALLOPHYTES

2. Fungi

c. Ascomycetes (Continued)

Peziza. The pezizas are commonly called "cup fungi", because the part of the plant above the substratum is cup-like. These plants are saprophytic, growing on dead branches and twigs in moist situations in the woods. Remember that what you are studying is only the part above the substratum which is associated with the production of spores. It is therefore called the *sporophore*. The vegetative mycelium is usually very extensively distributed throughout the substratum. Since this sporophore produces *ascospores*, the whole structure is called an *ascocarp*.

Make habit sketches of the cup-like ascocarp. With a sharp knife, remove a small amount of the inner lining of the cup (ascocarp), put it on a slide in a drop of water, and mash with a cover-slip. If you find the asci, what is this lining called? Draw an ascus. How many spores does each ascus have? Look at the vegetative part of the sporophore. Is this a filamentous plant? From prepared slides, draw a section of a hymenium.

Morchella. This is called morel and is edible. It grows up from the ground in moist woods. Draw one. What is this part of the plant called? Where do you suppose the asci are? Remove a small part of the inside of a depression and study under the microscope. Do you find the asci? Make drawings of them.

The Ascomycetes are of great economic importance because of the injury they do to some of our economic plants. The common mildews so pernicious to many shrubs, such as roses and lilacs, belong to this group. Examine leaves of rose or clover infected with powdery mildew. Examine the surface with the low power. With a sharp knife, scrape off some of the hyphae on a slide in a drop of water; examine with low and high power. Are the hyphae septate? How are the spores produced? What are these spores called? If ascocarps are present, study them also.

REFERENCE

Coulter, Barnes and Cowles, *Textbook of Botany*, I.

EXERCISE 19

II. THALLOPHYTES

2. Fungi

c. Ascomycetes (Continued)

Aspergillus. This is sometimes called Black Mould because of the black spores which it produces. This mould is common on cheese and on bread associated with *Mucor*. The best way to obtain the mould is to prepare plates of glucose agar and expose them to air for an hour or two. After twenty-four hours in the incubator, look for mould colonies, which you will readily recognize by their cobwebby appearance. After forty-eight hours, the colony should begin to turn black on top, which means that the spores are being produced.

Examine some of this mould in a weak solution of alcohol. The alcohol will evaporate rapidly, so you will have to see to it that it does not dry up. Ask yourself the following questions: How does this mould differ from Mucor? Is this also coenocytic? Does it have rhizoids? How are the spores produced? What are such spores called? What is the organ which produces the spores called? What are the spores produced in this way called? Make accurate drawings of the filaments (hyphae), *conidiophore, conidiospores*, and several stages in the development of the conidiophore. If necessary, use prepared slides. Sow some spores on a weak sugar solution and incubate. After twenty-four hours, examine and draw several stages in germination. This plant also reproduces sexually. If material is available, study this method of reproduction.

Penicillium. Blue or Green Mould. This is the most common mould on cheese. It can be obtained, however, by the same method as that used in obtaining *Aspergillus*. Its reproduction is very much like that of the latter. Proceed as with *Aspergillus*. What are the differences between the two plants? What are the economic uses of these moulds? Why?

REFERENCE

Harshberger, J. W., *Mycology and Plant Pathology*.

EXERCISE 20

II. THALLOPHYTES

2. Fungi

c. Ascomycetes (Continued)

Lichens. A lichen is not a plant, although it is generally considered one. It is usually a growth consisting of two plants, which are more or less interdependent. Consequently, a lichen may be more correctly defined as a life relationship. The two plants composing a lichen are a fungus and an alga. The relationship has usually been considered of mutual benefit, but some authorities consider the fungus as a parasite on the alga. If the former is true, the life relationship is *symbiosis;* if the second theory is correct, the relationship is *parasitism.* The reason for studying lichens at this time is that the fungus present in lichens is, with one or two exceptions, an ascomycete. The algae present are the unicellular green algae or the blue-green. Lichens are common on rocks and on the bark of trees where life conditions are more or less severe. They are the first plants to grow on bare rocks.

If possible, make a short field trip to where trees and exposed rocks are found. Try to determine the difference between lichens growing on trees and those growing on rocks; also see how many different kinds of lichens you can find.

Lichens are classified roughly into three kinds: *crustose, foliose,* and *fruticose.* From a number of specimens in the laboratory, determine to which class each belongs. Make habit sketches of each type and note where each one would be found. From a powdery lichen, which has been kept in a moist chamber over night, scrape a few particles on a slide in a drop of water or weak alcohol. Cover with a coverglass and examine under the microscope. Is the fungus filamentous? What type of plant is the alga? Make drawings from high power of hyphae and algae showing the relationship to each other. It is sometimes profitable to color the slide with eosin, which will color the fungus red. Do the hyphae have cross walls (septate)?

If the fungus is an ascomycete, how does it reproduce? On some lichens you will find cup-like structures. What are they? If the cup is small enough, remove it with a needle and place it

under a drop of water on a slide. Crush and cover with a cover-glass. Examine for spores and sporangia. What are these sporangia called? What are the spores called? Make a drawing from high power of an ascocarp with spores. Determine how many spores in each ascus and whether the spores are "single" or "double". If the cup is large, scrape off a piece of the inner lining of the cup and proceed as above.

How does the alga reproduce? This can be determined while making a study of the relationship between the fungus and the alga. Make drawings of this process.

REFERENCES

Fink, B., *Lichens of Minnesota;* Hasse, H. E., *Lichen Flora of Southern California.*

EXERCISE 21

II. THALLOPHYTES

2. Fungi

d. Basidiomycetes

The fungi included under this group are, like the Ascomycetes, distinguished by a peculiar sporangium called a *basidium*. The part which you are studying and which we usually call "mushrooms" is only the part of the plant associated with the production of spores. It is therefore a sporophore. The vegetative part of the mycelium is distributed throughout the substratum and is therefore out of sight. It is mould-like and is composed of branching filaments (hyphae). Typical Basidiomycetes usually grow on the ground, living on dead organic matter such as dead branches, stumps, etc. Such plants are, of course, saprophytic. Several are parasitic or partly so, growing on living plants, which they destroy sooner or later. The basidium is a sac-like structure, the walled-off end of a hypha, which produces usually four spores. These spores are, however, produced on the outside on special projections, the *sterigmata,* and are called *basidiospores.*

Mushrooms. Make a habit sketch of a gill mushroom. The "gills" are the blade-like structures hanging from under the cap. The stalk is called the *stipe;* the cap is called the *pileus;* and the ring on the stipe (if present) is called the *annulus* or *velum.* All gill mushrooms belong to the family Agaricaceae. Mash a piece of a gill on a slide, examine with a microscope, and draw spores under high power. Note their shape and outline. If there is a "cup" at the base of the stipe, it is called the *volva.* If material is available, draw several stages in the development of the mushroom. There are other mushrooms which do not have gills, but have pores instead, the inside of which is covered with spores. Make a sketch of one of these. From prepared slides of cross sections of gills, make drawings showing the structure, including basidia and basidiospores.

Puffballs. These Basiodiomycetes are called Gasteromycetes. Make a habit sketch of one. Notice the hard outer coat, the *peridium.* Where are the spores produced?

The Earth Star. This is one of the puffballs called *Geaster*. It can not very readily be distinguished from an ordinary puffball until it is mature. Then the outer coat splits like that of an orange when peeled. Upon drying, this skin turns back towards the ground and tears the plant loose from the substratum. When the wind blows it about, it turns over, and the spores are distributed through the opening.

Bird-Nest Fungus. The technical name for this peculiar Gasteromycete is *Nidularia*. Draw several stages in the development of this plant including a mature one. What is the "nest"? What are the "eggs"? Remove an "egg", place on a slide in a drop of water, and crush. Examine and draw a spore.

REFERENCES

Atkinson, G. F., *Mushrooms;* McIlvaine, C. and Macadam, R. K., *One Thousand American Fungi;* Marshall, N. L., *The Mushroom Book.*

EXERCISE 22

II. THALLOPHYTES

2. Fungi

c. Protobasidiomycetes

Ustilaginales. These are the so-called smuts. They are parasitic Basidiomycetes found on a great number of plants, especially the grasses. Since many of the grasses are among our most widely cultivated plants, this fungus is of great economic importance. It is common on oats, wheat, and corn. In corn it may occur in the tassel, on the ear, or in any part of the plant. Its usual occurrence is in the ovule (young seed), which becomes very much distorted and, when mature, is filled with black spores, often called "brand spores".

Study smutted wheat, oats, or corn. Make drawings of distorted seeds and of normal seeds for comparison. Also draw distorted flowers (male) from the tassel of corn and normal flowers. Place some spores on a slide in a drop of water, examine, and draw. If time permits, germinate spores in a sugar solution and draw. It is in connection with the germination of the spore that the basidium is produced. This is a short septate filament, which usually produces four spores, the basidiospores.

Uredinales. These fungi are commonly called rusts. They are also parasitic Basidiomycetes and attack a great variety of plants both wild and cultivated. These plants have the most complex life history of all fungi. The outstanding peculiarity of many of the rusts is that they require two different hosts on which to complete their life histories.

The rust which is most common in this part of the country is apple or cedar rust. The two kinds of hosts that this has are the red cedar and various species of plants belonging to the same family to which the apple belongs. Make a study of a cedar apple in autumn condition and sketch. This is a gall produced by the fungus. Study this growth in spring condition and draw. Remove one of the gelatinous protrusions and mount on a slide. Study and make drawings of the spores. What are these spores called? When these "spores" germinate they produce two basidia, which resemble the basidium of the smuts. Study leaves of the apple infected with rust. This is the sum-

mer condition of the fungus. This is called the cluster cup stage, and the spores produced are called *aecidiospores.* Make a similar study of wheat rust.

Study straw and leaves of wheat with "black rust". Scrape off some of it and study under the microscope. What are these spores called? This is the autumn or winter condition of the rust. Study leaves of the common barberry bush and draw. Study spores and draw. What are these spores called, and what is this stage? From the barberry, the spores go on the wheat. This takes place in the early summer. There it develops red rust spots. Examine these and draw. Remove some of the spores and examine under the microscope. These spores are called *uredospores.* Is this stage present in the apple rust? Compare the stages and respective hosts in the two rusts.

REFERENCES

Duggar, B. M., *Fungus Diseases of Plants;* Stevens, F. L. and Hall, J. G., *Diseases of Economic Plants;* Stevens, F. L., *Fungi Which Cause Plant Disease.*

EXERCISE 23

III. BRYOPHYTES

1. Hepaticae (Liverworts)

The great division of plants known as Bryophytes comprises the liverworts (Hepaticae) and the mosses (Musci). The characteristics of this group, as contrasted with the Thallophytes, are: (1) The establishment of a definite alternation of generations. Distinct sexual and sexless individuals alternately produce each other, the *gametophyte* producing the sex organs (containing gametes), the *sporophyte* producing asexual spores. The difference between the alternation of generations here and in the algae is that one (the sporophyte) is more or less dependent upon the gametophyte. (2) The appearance of the *archegonium*. This is the organ which produces the egg (female gamete). The archegonium is a flask-shaped organ consisting of a jacket of sterile cells. (3) The appearance of a multicellular antheridium. A multicellular antheridium was found among the algae in *Ectocarpus* and *Chara*, but this one is uniform throughout the Bryophytes and has a characteristic structure.

The liverworts are thallose plants found growing in moist situations along streams and lakes or in moist shady places in the woods. The gametophyte is the larger and more conspicuous generation. A characteristic feature of this plant is its dichotomous method of branching. They may be monoecious or dioecious, but, in either case, the sex organs are, as a rule, produced on the upper surface in depressions, grooves, or special elevations. When the egg is fertilized, it begins to grow into the sporophyte plant, which, in the liverworts, remains in the tissues of the mother plant and is more or less parasitic on it.

Riccia. This is the simplest of liverworts. Study the plant with the naked eye and with a magnifying glass. Make an accurate sketch of two kinds: the shorter, heavier one is more confined to ground or mud, the longer, narrower one to a floating habitat. From a prepared slide of longitudinal sections of this plant, search for archegonia. Notice the flask-like shape. Where is the egg located? How is fertilization brought about? When the egg is fertilized it begins a series of divisions. Look for divisions of the fertilized egg. This is the young sporophyte.

Look for stages where the cells are beginning to prepare themselves for production of spores. These cells are called spore-mother cells. Each cell gives rise to four spores. This group of cells is called a tetrad, and each spore is called a tetraspore. Draw a tetrad and a tetraspore. Draw also a mature sporophyte. What becomes of the archegonium? The sporophyte in this plant is, therefore, nothing more than a sporangium, the simplest sporophyte you can imagine.

Although this plant is monoecious, you seldom find both male and female organs in the same plant. The reason is, that the antheridia are usually produced first. From prepared slides of younger plants look for antheridia. Make a drawing of a mature antheridium. Notice the sterile jacket of cells on the outside and the many-celled structure of it as a whole. Each cell on the inside produces a motile sperm.

REFERENCES

Campbell, D. H., *Mosses and Ferns;* Grout, A. J., *Mosses With a Hand Lens;* Evans, A. W. and Nichols, G. E., *Bryophytes of Connecticut.*

EXERCISE 24

III. BRYOPHYTES

1. Hepaticae (Continued)

Marchantia. This plant is a more advanced type than *Riccia*. What does that mean? In studying this plant, recall *Riccia*, and see how this differs from it. Study the plant as in the previous period. You will receive two plants. Why? Make careful sketches of the two plants. The stalk-like structures on the plants are the receptacles of the sex organs. How do they differ? Look for the rhizoids on the under side. This is called the ventral side; the upper side is the dorsal. Also make a habit sketch of the plant showing cupules on the dorsal side. With a pin or needle, remove some of the green bodies found in the cup, put on a slide, and examine with low power. Make a drawing of one. These are asexual reproductive bodies. They are called *gemmae*. Has this plant any other asexual method of reproduction?

The archegonia are located on the under side of the female receptacle, hence they are inverted. From prepared slides of sections of the receptacle, make drawings of archegonia showing the eggs. Draw a young and an old archegonium. From other prepared sections of the male receptacle, draw an antheridium. On which side of the receptacle are they located? This plant is said to be dioecious. What does this mean? Since the two sex cells, the egg and the sperm, are located in different plants more or less distantly separated, how is fertilization brought about? Does this have any relation to the plant's habitat?

After fertilization has taken place what happens? From prepared slides of female receptacles, study the development of the fertilized egg. What does the egg develop into? Make a drawing of a young sporophyte. Also make a drawing of a mature sporophyte. How does this sporophyte differ from the one in *Riccia?* What is the part in which the spores are found called? The part which attaches it to the plant is called the *foot*, and the tissue between these two extremes is called the *seta*. Under high power, study the spores. Is there anything besides the spores in the sporangium. The string-like bodies mixed with the spores are called *elaters*. What is their function? What is

the function of the foot and seta? Compare this sporophyte with that of *Riccia*. What is the main difference between them? This morphological difference is associated with nourishment and spore dispersal.

Anthoceras. Make habit sketches of this plant. Notice that some plants have a projection on the dorsal side, while in some it is absent or very short. This is the sporophyte. What important difference do you observe in this sporophyte and in the others studied so far? Obtain from the instructor a small piece of a mature sporophyte. Mash on a slide and examine. Draw a spore. From prepared slides of longitudinal and cross sections of the sporophyte make a sketch showing structures of the sporophyte. This is considered one of the most advanced types of liverworts. Explain.

REFERENCES

Grout, *Mosses with a Hand Lens;* Evans and Nichols, *Bryophytes of Connecticut.*

EXERCISE 25

III. BRYOPHYTES

2. Mosses (Musci)

Mosses are closely related to some of the higher (leafy) liverworts. The characteristic differences between the two will be noticed in studying them.

Sphagnum. This is known as bog or peat moss. It grows almost everywhere where the soil is saturated with water and especially where the soil is sour (acid). This does not mean that it does not grow also in other moist situations. The plant which you are studying is the gametophyte. What is peculiar about this gametophyte as compared with that of the liverworts studied? Make a habit sketch of one. What is the black knob at the tip? With a pin, remove a "leaf", place under microscope, examine, and draw. Notice that it is made up of two kinds of cells, some large with openings in them and others very long and narrow. The former are dead (hyaline) cells, while the latter are living and contain chlorophyll. What effect does this have upon the color of this plant? This plant has antiseptic properties and is a good absorbent. Why? The stalk which holds the sporophyte is called the *pseudopodium* (false foot). Why? Under a magnifying glass, draw a complete sporophyte with the lid on and one with the lid off.

True Moss (Bryales). In studying true moss, determine just how it differs from the liverworts and *Sphagnum*. Most mosses are dioecious. The sex organs are located at the tip of the plant inside of a crown of leaves often called the moss "flower". Make sketches of male and female plants. How does this gametophyte differ from the gametophyte of some of the Thallophytes? What are some of the organs present in this plant? What is the function of each of these organs? Your drawings should show "leaves", "stem", and rhizoids. In some mosses asexual bodies occur. Look for them.

With a needle, remove the extreme tip of the male plant on to a slide, cover with water and a coverglass, and mash without breaking the coverglass. Examine. You should find antheridia. Draw one. Now do the same with the female plant. What should you find in this one? Draw an archegonium. If material

is available, draw also a young sporophyte. Determine what becomes of the old archegonium after the egg begins to grow.

Study a moss plant with the sporophyte. Which gametophyte plant does it grow on? Why? Make a careful drawing of the whole plant. Pull out the sporophyte and study it with a magnifying glass. Try to name the different parts. The paper-like funnel which is attached on the capsule is called the *calyptra.* What has it come from? Draw the capsule with the calyptra removed. With a needle, remove the lid, the *operculum.* Draw it and the capsule with operculum removed. With a lens, examine the tip of the capsule (sporangium). Make a drawing of what you see. This is called the *peristome.* Its function is to remove the spores. Crush a capsule and draw the spores.

When a spore germinates it does not produce the leafy gametophyte directly; it produces an alga-like growth. This is called the *protonema* (the first thread). Examine some of these and draw.

REFERENCES

Grout, *Mosses With a Hand Lens;* Grout, A. J., *Mosses With a Hand Lens and Microscope.*

EXERCISE 26

IV. PTERIDOPHYTES

1. Ferns

Pteridophytes are the fern plants. The outstanding characteristic of these plants is the presence of a highly developed and complex sporophyte and a reduced and simplified gametophyte. In Bryophytes the gametophyte is the outstanding generation; in the Pteriodophytes the sporophyte is the outstanding generation. In Bryophytes the sporophyte is more or less dependent on the gametophyte; in Pteridophytes the sporophyte has an independent existence.

Filicales. These are the true ferns. Study a complete fern plant. Bear in mind that you are studying the sporophyte. Notice, this plant has leaves, stem, and true roots. What is the function of each? Make a sketch of a leaf. The green or brown patches ("fruit dots") on the under side of the leaf are called *sori*. Draw some under a magnifying glass. With a needle, remove the green cover, the *indusium*. With a needle, remove some of the sporangia on to a slide, add water and a coverglass, and study. Make a careful drawing of a sporangium. Then mash and draw the spores. The thick-walled, U-shaped cells on the edge form the *annulus*. What is its function? How are the spores shed?

A leaf producing spores is a *sporophyll*. Study and draw a plant in which all leaves are not sporophylls. Some leaves are specialized to bear spores, while others are only vegetative.

When a spore germinates, what does it produce if the plant has alternation of generations? Examine a gametophyte with a magnifying glass and draw both dorsal and ventral sides. This plant is monoecious, and the sex organs are located on the ventral side. Can you see them with a magnifying glass? What plant does this gametophyte resemble? Next draw a gametophyte with the young sporophyte attached. How did this arise?

From prepared slides, make drawings of archegonia and antheridia. From other prepared slides, make diagrammatic drawings of cross sections of stems and roots of ferns. The outermost tissue is the *cortex*. The thick-walled cells make up the *xylem*. The tissue inside the xylem, if any, is the *pith*. The

xylem and the *phloem* together are called the *stele.* There are three principal types: the *protostele,* such as the one in the root; the *siphonostele,* such as the one in *Adiantum;* and the *polystele,* such as the one in brake fern (*Pteris*).

REFERENCES

Clute, W. N., *The Fern Allies of North America;* Waters, C. E., *Ferns;* Underwood, L. M., *Our Native Ferns.*

EXERCISE 27

IV. PTERIDOPHYTES

2. Lycopodiales

These fern plants are commonly called club mosses because of the moss-like stem and their club-shaped appearance due to the large terminal strobili which some have. Besides the above characteristics, which are not found in ferns, they differ from ferns mainly in that in most of them the spore-bearing leaves, the sporophylls, are crowded together at the summit of the stem. This collection of sporophylls makes up what is called the *strobilus*.

Lycopodium. There are several species of *Lycopodium*. The one you will study is *Lycopodium complanatum*. Make a habit-sketch of the whole plant. Then, with a needle, remove carefully a sporophyll and put it on a slide in a drop of water. Study it with a magnifying glass. Make a drawing of the upper side (the adaxial side), of the under side (the abaxial side), and of the side view. Is the sporangium single or double? On which side of the sporophyll is it? Then, mash it with a coverglass and draw spores.

From prepared slides, make a diagrammatic drawing of a cross section of the stem. What kind of a stele has this plant? The gametophyte of *Lycopodium* is a tuberous subterranean structure. If available, study and sketch.

Selaginella. This plant is common along ditches and ponds. Make a drawing of the whole plant showing stem, leaves, strobili, and roots. Where do the roots appear? One peculiarity of *Selaginella* is that the spores are different. In the ferns already studied, the spores look alike. This is called *homospory*, and all such ferns are said to be *homosporous*. *Selaginella*, on the other hand, having different spores, is *heterosporous*, and this situation is *heterospory*. The different spores may be seen in a longitudinal section of a strobilus. From a prepared slide of this, make a drawing showing the different spores in the same strobilus. The small spores are called *microspores*. They give rise to the male gametophyte and may, therefore, be called male spores. The sporangium which holds the microspores is the *microsporangium*, and the sporophyll which produces the microsporangium is

the *microsporophyll*. The large spores are called *megaspores*. They produce the female gametophyte and are, therefore, female spores. What is the sporangium called which produces the large spores? The sporophyll?

Remove a sporophyll which bears large spores, examine with lens, and draw. On which side are the sporangia on this plant? Break a sporangium with a needle and draw. Do the same with the microsporophyll.

If available, draw sections of male and female gametophytes. Also draw a female gametophyte with the young sporophyte attached to it.

REFERENCE

Coulter, Barnes and Cowles, *Textbook of Botany*, I.

EXERCISE 28

V. FIELD STUDY

Plant Life in the Autumn. The purpose of field work is to familiarize the student with plants in their native habitat—to study the plants at home. The student should observe every plant he sees. He should notice the following things: what kind of a plant it is, where it grows, what stage it is in, etc. It is well to bring a magnifying glass, a note book, pencil, and some bottles and pipettes. Take notes of everything learned and write up the trip as soon as possible, while your memory is fresh. Be especially careful about the organization of the paper. Scattered facts do not mean much. State the facts in some orderly fashion together with the conclusion you have reached.

PART TWO

OUTLINE OF PART II

I. THE CELL

1. Cell Division
2. Cell Differentiation

II. SPERMATOPHYTES (SEED PLANTS)

1. Gymnosperms
   - *a. Cycads. Zamia*
   - *b. Conifers. Pine, etc.*
2. Angiosperms
   - *a. Seeds*
     - (1) Morphology
       - (a) External Characters
       - (b) Internal Characters
       - (c) Foods Stored in seeds
     - (2) Germination
       - (a) Conditions Under Which Seeds Germinate
       - (b) Respiration in Seeds
       - (c) Growth of Seedlings
   - *b. Roots*
     - (1) Kinds of Roots
     - (2) Structure of Roots
     - (3) Physiology of Roots
   - *c. Stems*
     - (1) Kinds of Stems
       - (a) Dicotyledonous Stems
         - a. External Characters
         - b. Internal Characters
       - (b) Monocotyledonous Stem
         - a. External Characters
         - b. Internal Characters
       - (c) Modified Stems

(2) Physiology of Stems

(a) Rise of Sap in Stems

(b) Geotropism

(c) Phototropism

(d) Effect of Light on Growth

d. Buds

(1) Location of Buds

(2) Kind of Buds

(3) Structure of Buds

e. Leaves

(1) Morphology of Leaves

(2) Kinds of Leaves

(3) Phyllotaxy

(4) Physiology of Leaves

(a) Transpiration

(b) Photosynthesis

f. Flowers, Flower Clusters, Fruits, Etc.

(1) The Willow (Salix)

(2) The Oak (Quercus)

(3) Cinquefoil (Potentilla)

(4) May Apple (Podophyllum)

(5) Wood Sorrel (Oxalis)

(6) Vetch (Vicia)

(7) Iris (Blue Flag)

(8) Daisy (Chrysanthemum)

(9) Dandelion (Taraxacum)

g. Embryogeny (in Capsella)

h. Fruits

i. Seed dispersal

3. Classification and Indentification

III. FIELD STUDIES

EXERCISE 1

I. THE CELL

Cell Division. Using prepared slides of longitudinal section of root tips of *Tradescantia virginica* (Spiderwort), or some other plant, make a study of cell division. This shows a *meristimatic region.* Under high power, draw accurately at least eight consecutive stages in the division of the nucleus.

In your notes, answer the following questions: What is a meristimatic region? What is the function of cell division? What are *chromosomes?* What is the function of chromosomes? What is the function of the nucleus? In what part of the root tip is cell division most abundant? What is the difference in appearance, size, and shape between the cells in this region and those which are not dividing? What is meant by "constancy of chromosomes"? What is the distinction between *mitosis* and *amitosis?*

Cell Differentiation. From prepared slides of the cross section of a stem, make accurate drawings of as many different cells as you can find. How do these cells differ from the cells studied in the root tip? How do they differ from each other? What is a group of similar cells called? Where does the thick wall come from? Do all these cells have protoplasts? If they do not, what kind of cells are they?

REFERENCE

Sharp, *An Introduction to Cytology.*

EXERCISE 2

II. SPERMATOPHYTES

1. Gymnosperms

a. Cycads

Zamia. These are the simplest of the living seed plants. Make a habit sketch of *Zamia pumila.* Note the tuberous stem and compound leaves. All of them are tropical to subtropical. This plant grows in Florida. Note also the position of the strobilus (cone). Make a drawing of a female strobilus. From a broken cone, secure a megasporophyll and draw it. Where are the megasporangia? In some cones the megasporangium is small. What does this mean? Secure a seed and sketch it, showing the *micropyle.* With a sharp knife, split the seed open and study the contents. Draw, showing the different parts of the *embryo* and seed coats. Make a drawing of a section of a seed showing archegonia. Make a drawing of a male strobilus. How does this differ from the female strobilus? From a broken cone, secure a microsporophyll and draw side and lower views. What are the small spheres on the under side? Draw one, using a magnifying glass. Mash a microsporangium on a slide and examine under a microscope. Draw a few microspores.

How do these plants differ from the ferns? How do they differ from *Selaginella?* What is the seed? What does the *endosperm* come from? From external and internal appearances the seeds look alike. Are they? Explain. Where is the female gametophyte? What structure in this plant is called *pollen?* What does this structure correspond to in *Selaginella?* What is the function of the *pollen tube?* The sperms in this plant have cilia; what does this signify? How is fertilization brought about in this plant? What is *pollination?* How does it take place in this plant?

REFERENCES

Chamberlain, C. J., *The Living Cycads;* Coulter, Barnes, and Cowles, *Textbook of Botany,* I.

EXERCISE 3

II. SPERMATOPHYTES

1. Gymnosperms

b. Conifers

Pine (*Pinus*). This is the most widely distributed gymnosperm. Make a habit sketch of a twig of pine showing leaves and the old female strobilus. How many leaves are there in each bunch? From prepared slides, make a careful drawing of a cross-section of a leaf. What does the shape and structure of this leaf signify as to climatic conditions to which this plant is adapted? Make a diagrammatic drawing of a cross-section of a young shoot. Explain how the stem increases in thickness.

From what part of the stem does wood come? What is it called. What is its function? From prepared slides, make accurate drawings of cross, tangential, and radial sections, showing *medullary rays, bordered pits,* and *rings of growth.* Make a diagram of a stem showing how these sections were cut. From these three sections, reconstruct a *tracheid* showing form and position of bordered pits. What is the function of the bordered pits? Medullary rays? What are rings of growth? How do they appear in wood to the naked eye? What is the summer and autumn wood? Which is the spring wood? What difference is there in the cells of each? What is the explanation for this difference? Discuss the economic uses of pines. Discuss their present and past distribution.

Other gymnosperms are Red Cedar *(Juniperus),* Arbor Vitae *(Thuja),* Larch *(Larix),* Cypress *(Taxodium),* etc. Make habit sketches of as many of these as are available.

REFERENCES

Coulter, Barnes and Cowles, *Textbook of Botany,* I; Coulter, J. M. and Chamberlain, C. J., *Morphology of Gymnosperms.*

EXERCISE 4

II. SPERMATOPHYTES

1. Gymnosperms

b. Conifers (Continued)

Pine (*Pinus*) *Reproduction.* Make a sketch of a female strobilus. From a broken cone (strobilus), remove the bract-like structure and draw side and upper views. What is this structure? In what way does it differ from the corresponding structure in Sycads? From prepared slides, draw a section through a megasporangium showing gametophyte with archegonia. Draw a mature seed. How does this differ from the seed in Cycad? What is the function of the bract (wing)? Draw a young pine (seedling). Make a drawing of a male strobilus. How does it differ from the female? From a broken cone, (strobilus) secure a microsporophyll and draw side, end, and under side views. How does this differ from the microsporophyll of Cycads? Mash a microsporangium on a slide and examine under a microscope. Draw a few microspores (pollen grains). How do they differ from the pollen in Cycads? From prepared slides, diagram the longitudinal section of a male strobilus. From cross sections of a mature male strobilus, make a careful drawing of a pollen grain under high power, showing cell walls and nucleus or nuclei.

Are pines monoecious or dioecious? How is pollination brought about? What is meant by gymnosperms? Where does the microspore germinate? What is it called after it germinates? Does the male gametophyte of gymnosperms have an antheridium? How many sperms does it produce? The sperms in pine are non-motile. What does this signify?

REFERENCES

Coulter and Chamberlain, *Morphology of Gymnosperms;* Coulter, Barnes and Cowles, *Textbook of Botany,* I.

EXERCISE 5

II. SPERMATOPHYTES

2. Angiosperms

a. Seeds

Morphology of Seeds (External Characters). Examine the seeds and note their color, surface, and markings. Look for a scar (*hilum*), the place where it was attached to the inside of the fruit. Look for a small swelling (the *chalaza*). Look for the ridge (the *raphe*) which runs around some seeds. Look for a tiny opening (the micropyle). Describe and draw the outside view of each seed studied and name all parts shown. Note *caruncle* on the castor bean. What is its function? Draw a seed of cotton and milkweed. What is the function of the lint for the plant?

Examine seeds soaked and dry. What is the effect of soaking seeds? How does the water enter the seed? What is the result?

Internal Structure. Dissect the different seeds and note the following structures: seed coat (testa), endosperm, embryo. Make drawings of inside views of the seeds showing the different parts. Classify seeds as to internal structure. What is the embryo? How does the embryo of the bean differ from the embryo of corn and of the castor bean? What are, *cotyledons, radicle, plumule?*

Foods in Seeds. Scrape off a little from the inside of a seed on to a slide. Put on this a drop of iodine. Examine under the microscope. The blue particles are starch. Make drawings of starch from corn, bean, and pea under high power. Put iodine on the inside of other seeds. Which have starch? In what part of the seed is it? What seeds have no starch? In what forms is food stored in seed? Why are seeds of economic value? What are seeds used for besides food? What is the function of stored food in seeds?

REFERENCES

Coulter, Barnes and Cowles, *Textbook of Botany,* II; Ganong, W. F., *A Textbook of Botany;* Martin, J. N., *Botany with Agricultural Applications;* Weatherwax, P., *The Story of the Maize Plant.*

EXERCISE 6

II. SPERMATOPHYTES

2. Angiosperms

a. Seeds (Continued)

Seed Germination. Examine the four bottles labeled *A1*, *B1*, *C1*, and *D1*. Make sketches of them showing the condition of the seeds. In which bottle have the seeds germinated best? Why have not the seeds germinated in the other bottles? Explain.

Examine the three bottles labeled *A2, B2, C2*. A2 has been kept outside; B2, on a radiator; C2, in a warm room. Which has germinated best? Explain. Make drawings of the bottles, showing the condition of the seeds.

Glue a piece of cotton on the bottom of a tumbler. Put a few soaked seeds in a small dish placed in a Petri dish filled with water. Light a match and ignite the cotton in the tumbler and quickly invert it over the seeds. What happens? Explain. Examine at the following period. Make drawings of the two tumblers, indicating differences, and explain fully.

Secure some lime water or barium hydroxide. Put some in a glass and blow into it with a glass tube. What happens? Explain. Germinate some oats in a closed bottle with a tube passing through the cork. After a day or two, pass the gas above the seeds into lime water by filling the bottle with water through a funnel. What happens? Explain. Draw the apparatus. Draw a respiroscope and explain its use.

Examine germinatng seeds of squash. What part of the embryo comes out of the seed coat first? Note the root hairs. Do the cotyledons in the squash turn green? Draw several stages in the germination of the squash.

Study germinating seeds of pea, bean, corn, and oats. How does the germination of the pea differ from the germination of the squash? How do the germination of corn and oats resemble each other? How do they differ from germinating seeds of other plants studied? What is meant by *hypogeal* and *epigeal* germination? Draw several stages in the germination of corn, pea, bean, and oats.

REFERENCES

Coulter, Barnes and Cowles, *Textbook of Botany,* II; Ganong, *Textbook of Botany;* Martin, *Botany with Agricultural Applications.*

EXERCISE 7

II. SPERMATOPHYTES

2. Angiosperms

b. Roots

Kinds of Roots. Make a study of a root of clover. The root coming directly below the stem is the *primary root.* Note that the root has branches. These are *lateral roots.* Note the *tubercles.* From prepared slides, make a diagrammatic drawing of sections of tubercle and root. Under high power, draw a few cells from the tubercle, showing bacteria. What relationship is shown here? Of what biological significance are these bacteria? What effect do they have upon the soil? What would happen to plants if such organisms did not exist?

Make a study of the root of dandelion. How does it differ from the root of clover? The main root is called the *tap root.* Also make a study of turnip or parsnip root. This tap root is known as a fleshy root. Place some scrapings from the inside of the root on a slide in a drop of iodine. Does it contain starch? What is the function of the fleshy root? What relation is there between these plants and the flowering period? Fleshy roots of dahlia are called *fascicled roots.* Make a list of roots used as foods?

Study the stem of ivy and wandering jew. Roots occurring in unusual places are called *adventitious roots.* If they grow on aerial parts they are called *aerial.* What is the function of aerial roots in ivy? In wandering jew? In strawberry? Do they appear in any special part of the stem? Why?

Study roots of corn, wheat, or any grass plant. These are called *fibrous roots.*

Structure of Roots. From prepared slides of a longitudinal section of a root tip, make a diagram showing the *root cap.* What is its function? From prepared slides, make a diagrammatic drawing of a cross section of a root. Does the root have bark? Does it have wood (xylem)?

Physiology of Roots. What is the function of roots? Explain fully. Study demonstration experiments to show how roots absorb water (*osmosis*). Explain. Draw apparatus. How do roots absorb inorganic salts. Study the experiment showing

roots forcing water up the stem (root pressure). Explain. Study the experiment showing the effect of gravity on root. What is a *tropism?* Is this positive or negative, and what is this tropism called?

REFERENCES

Coulter, Barnes and Cowles, *Textbook of Botany*, II; Ganong, *A Textbook of Botany;* Martin, *Botany with Agricultural Applications.*

EXERCISE 8

II. SPERMATOPHYTES

2. Angiosperms

c. Stems

Dicotyledonous Stem. Examine the stems of alder and cherry. These are woody stems. Stems with little wood (e.g. *Coleus*) are called herbaceous stems. Do the branches appear singly or in groups? Where are the *leaf scars*? What relation do the buds have to the leaf scars? The portion of the stem where a branch or leaf scar is found is called a *node*. The portion between the leaf scars is called an *internode*. The branching of alder is called alternate or spiral. Lood for *bud scars*. From these scars can you tell the age of a branch? Do you find any other markings on the bark? Make sketches showing method of branching, position of buds, leaf scars, bud scars, and *lenticels*.

Examine a stem of maple, ash, or lilac. Compare this with the stems above. What is the difference in branching? Note other differences. Are the buds of any one pair directly above those of the next lower pair? This branching is called opposite. Make a sketch showing the characters mentioned above.

Diagram the cross section of a young stem of basswood. Label the different parts. Also diagram a section of *Ampelopsis* (ivy) stem. Make a careful and accurate drawing of a sector of the section of *Ampelopsis* including a vascular bundle.

Monocotyledonous Stem. Make a careful study of the stem of corn, bamboo, or wandering jew. How do they differ from the stems studied above? Note the definite nodes and internodes. Do these stems have bark? Do they branch? If so, how? Make a sketch showing all external characters.

From prepared slides, diagram a cross section of a stem of *Asparagus*. Also make an accurate drawing of a section of a stem, including a vascular bundle. How does the internal structure of the stem of monocotyledons differ from that of dicotyledons?

Modified Stems. Examine a flat-stemmed (*Muehlenbeckii*) plant. How does this stem differ from other stems studied? How does it resemble a leaf?

Examine the underground stem of Solomon's Seal. Why is this called a stem? Where are the nodes and internodes? One internode is produced each year. The attached leaf is the winter leaf. Look for the bud. Where are the roots attached? What is the function of the underground stem? Test it for starch.

Study a potato. This is called a *tuber*. It is an underground stem. What are the "eyes"? Draw a potato not sprouted and one which is sprouting. Test the potato for starch. Draw a few starch grains.

Study *corms* of gladiolus. This is also an underground stem. Make a sketch of a whole stem and of one which is split. In your notes enumerate the functions of stems and their economic uses.

REFERENCES

Ganong, *A Textbook of Botany;* Strassburger, *Textbook of Botany* (5th Ed.); Coulter, Barnes and Cowles, *Textbook of Botany,* II; Martin, *Botany with Agricultural Applications;* Coulter, J. M. and Chamberlain, C. J., *Morphology of Angiosperms.*

EXERCISE 9

II. SPERMATOPHYTES

2. Angiosperms

c. Stems (Continued)

Physiology of Stems. Cut off a piece of geranium stem about three inches long. This is a dicot stem. Cut off the leaves near the stem. Place the lower end in a solution of eosin. After an hour, examine. Does the red solution rise in the stem? What makes it rise? Make a thin section of the stem with a scalpel. Mount on a slide and examine with a lens. In what part of the stem does the eosin rise? Make a diagram of the stem section showing where the solution rises.

Cut off a piece of wandering jew and place it in eosin solution. This is a monocot stem. Proceed as above and make the same observations. Make a section, examine with lens, and diagram as above. Note differences between a dicot and a monocot stem.

Mash a piece of an herbaceous stem on a slide; add water and coverslip. Examine the tubes *(tracheae)*. How do these tubes differ from the tracheids in pine? Make drawings of *spiral* and *pitted ducts*.

Make a sketch of a young plant placed horizontally. After a few days, examine and draw again. What has happened? What relation is shown in this experiment? What is this phenomenon called? Compare this with a similar root experiment. What kind of a tropism is shown here? Is it positive or negative?

Make a sketch of a plant placed in such a way that it is illuminated from one side only. Examine after a few days. What has happened? What relation is shown in this experiment? What is this phenomenon called?

Place a young corn plant in a perfectly dark room. Leave for several days. Examine and note results. What effect does light have on development of chlorophyll? What direct effect does light have on growth?

REFERENCES

Ganong, *A Textbook of Botany;* Coulter, Barnes and Cowles, *Textbook of Botany,* II; Dixon, H. D., *Transpiration and the Ascent of Sap in Plants.*

EXERCISE 10

II. SPERMATOPHYTES

2. Angiosperms

d. Buds

Examine twigs of various woody plants, such as ash, alder, maple, beech, and sweet gum. Note the position of the buds in the *axils* of the leaves. Define axil. If the stem has no leaves, their position will be indicated by leaf scars. Note the size, shape, color, character of surface, and the number of buds at a node on the different plants. Do you find more than one bud in any one axil? If there are more than one, the others are called *accessory buds*. Do you find buds in other places than in the axil of the leaf? Such buds are called *adventitious buds*. Do you find a bud at the top of the branch? Such a bud is called a *terminal bud*. Buds which appear in axils of leaves are called *lateral buds*. Classify buds according to position.

Sketch buds of the different types, being careful to show the external characteristics of each one.

With forceps, carefully loosen the bud scales of the lateral buds of the sweet gum. Arrange these buds in a row on a sheet of paper and sketch. Compare the inner and outer surface of the scales. What do you find inside the scales? Make a sketch of the bud after the scales are removed. The arrangement of the leaves in the bud is called vernation. Note the arrangement. Pull off the young leaves, place them on paper, and sketch.

Remove the scales from one of the larger terminal buds. What do you find in this type of bud? Classify buds by contents.

Make a median longitudinal section through a bud on a twig with a sharp scalpel. Examine the outside and sketch. Is the bud continuous with the stem? Why?

What is the function of buds? Supposing that at some time in the past plants had no buds, explain how they may have arisen.

REFERENCES

Martin, *Botany with Agricultural Applications;* Smith, G. M.; Overton, J. B.; Gilbert, E. M.; Denniston, R. H.; Bryan, G. S. and Allen, C. E., *A Textbook of General Botany.*

EXERCISE 11

II. SPERMATOPHYTES

2. Angiosperms

c. Leaves

Morphology of Leaves. Study leaves of geranium (*Perlargonium*). Note the shape of the blade and the arrangement of veins. This vein type is called palmate. Is the edge smooth or uneven? Is the epidermis smooth or hairy? What is the *petiole?* Does it have *stipules?* Draw the entire leaf, showing the three main parts of a leaf, veins, and the character of the edge of the leaf. This is a dicot leaf.

Carefully remove a piece of the epidermis, mount on a slide, and study under the microscope. Do all the cells in the epidermis have chlorophyll? What cells have? Why? Draw a piece of the epidermis showing the shape of cells and *stomata.* Also draw an epidermal hair. What is the function of these hairs in geranium?

Carefully remove a piece of the epidermis from the under side of the leaf. Mount and study as above. Also draw a piece showing the things seen above. Do you notice any differences? If so, what are they?

Study a leaf of wandering jew. Note the vein arrangement, shape of blade, and edge. This is a typical monocot leaf. Is it a complete leaf? What part or parts are missing? Draw carefully, showing all the characters noted above. How does it differ from the geranium leaf?

Carefully remove a piece of the epidermis on the upper side. Mount, study, and draw as above. Note the differences from geranium leaf epidermis.

Remove a piece of the lower epidermis. Mount, study, and draw as above. How does this epidermis differ from the upper? From what you have seen, enumerate differences between the two leaves studied.

From prepared slides, study a cross section of some typical leaf. Draw accurately a cross section showing the following structures: upper and lower epidermis, stomata, *air chambers, mesophyll,* and *palisade cells.*

In your notes, discuss and answer the following questions: Why is a leaf usually flat and thin? Why does not the epidermis have chlorophyll? Why do guard cells have chlorophyll? What is the function of guard cells, and how do they work? What are air spaces for? What is the function of the palisade cells? How are they specialized to meet this function? Why are stomata usually found only on the lower side?

Discuss fully the function of leaves.

REFERENCES

Ganong, *A Textbook of Botany;* Strassburger, *Textbook of Botany* (5th Ed.); Martin, *Botany with Agricultural Applications.*

EXERCISE 12

II. SPERMATOPHYTES

2. Angiosperms

e. Leaves (Continued)

Compound Leaves. Examine leaves of clover, vetch, elder, Virginia creeper. These plants have compound leaves. Each small leaf is called a leaflet. Note the number and arrangement of leaflets. Compare with venation studied in simple leaves. Compound leaves are named in the same way; e.g. palmate, pinnate, etc., compound.

Modification of Leaf Structures. Examine leaves of vetch, smilax, barberry, and grape. Which are simple? Which compound? Look for the three parts of a leaf. What kind of stems are present in vetch, smilax, and grape? How are these stems held up? What structures are modified to hold the plant up in each case? What structures are modified into spines in barberry? Make drawings showing these modified leaves.

Examine leaves of sundew, pitcher plant, and Venus Fly-trap. How are these modified? What function have these leaves assumed? In your notes explain how these leaves function? Also examine with a hand lens the water plant, *Utricularia,* and draw.

Phyllotaxy. Study leaf arrangements of the following plants: Japanese honeysuckle, *Galeum*, etc. Note the number of leaves at each node. Two leaves at a node are called opposite; more than two, whorled; one at a node, alternate. In alternate leaved plants, work out the leaf formulae. Select a leaf, then, beginning with the next leaf above, count the number of leaves, including the leaf directly above the one selected. Now determine the number of times required to go around the stem. Use the number of the leaves as the denominator and the number of times required to go around the stem as the numerator. You now have a fraction which expresses the formula of leaf arrangement. This is called phyllotaxy.

Study of Transpiration. Cut off a geranium leaf near the stem. Put the petiole through a hole in a piece of cardboard. Place the cardboard over a tumbler of water so that the petiole extends an inch or so in water. Cover the whole with another

inverted tumbler. Leave for some time and observe. Where does the moisture on the sides of the inverted tumbler come from?

Place a branch with leaves of some woody plant in the potometer. Seal the space around the stem air tight. Adjust the colored water column in the graduated tube. Why does it move? Take the time and determine how many spaces it moves per unit of time in the darkened room. Try it in the window where there is a breeze but no sunlight. Does it move faster? Why? Try it in the sunlight. Does it move faster? Why? In your notes discuss fully transpiration.

REFERENCES

Ganong, *A Textbook of Botany;* Coulter, Barnes, and Cowles, *Textbook of Botany*, II; Martin, *Botany with Agricultural Application;* Dixon, *Transpiration and the Ascent of Sap in Plants.*

EXERCISE 13

II. SPERMATOPHYTES

2. Angiosperms

e. Leaves (Continued)

Study of Photosynthesis. Place a potted geranium plant with large, healthy leaves in a perfectly dark room. Leave it for twelve hours. Place a light screen on it with spaces exposed. Place the plant in a window in a good light and leave for an hour. Remove a leaf from the plant before exposing it to the light, one after the plant has been exposed, and the one with the light screen. Place these in hot water, then in alcohol until leaves are white. Wash in water. Then put in a weak iodine solution on a flat white dish. Which leaves turn blue? Do the leaves turn blue all over? Recall your test for starch in seeds. Explain.

Place a water plant (*Elodea* or *Myriophyllum*) under an inverted graduate filled with water. Place one in a dark room and another in light. Observe after several hours. Is the water replaced by gas in graduates? In which graduate is it replaced more? What is this gas?

Collect a quantity of rich green leaves. Place them in alcohol and heat until the alcohol has turned a rich green. Pour off the liquid in a bottle. Examine in transmitted and reflected light. The appearance of a different color in reflected light from transmitted light is called fluorescence. This is one property of chlorophyll. What is the color in reflected light?

Examine the demonstration photosynthometer and sketch. Your instructor will explain how it is operated. Then solve this problem. Suppose you have added carbon dioxide to air till you have a ten per cent. mixture of carbon dioxide. What percentage of oxygen will you have? After leaving in light until all of the carbon dioxide has been used up, what percentage of oxygen will you have at end of the experiment.

REFERENCES

Ganong, *A Textbook of Botany;* Coulter, Barnes and Cowles, *Textbook of Botany*, II; Martin, *Botany with Agricultural Applications.*

EXERCISE 14

II. SPERMATOPHYTES

2. Angiosperms

f. Flowers

Willow (*Salix*). Note that there are two kinds of bodies growing on the branches. Each of these bodies is composed of many flowers. These occur on different plants. This body is called a *catkin* or *ament*. Draw branches, showing the two kinds of catkins.

Examine a yellowish catkin. Note the yellowish organs composed of a stalk with an enlarged body at the end. The whole organ is a *stamen*. The stalk is the *filament*, and the knob is the *anther*. How many divisions in each anther? Note that a yellowish powder falls from the anthers. This is the pollen. How many stamens in a group? Notice the scale below each group. Is this scale smooth or hairy? Remove a scale with its stamens. These stamens with their scale constitute one kind of a flower in the willow. It is called a *staminate flower*. What is a stamen in terms of alternation of generations? A staminate flower? Draw a flower showing scale and stamens. Examine some pollen grains under high power. Are they smooth or rough?

Examine the other kind of catkin. Note the scales. Note also the flask-shaped green body in each scale. It is called the *pistil*. The brownish part at the top of the pistil is called the *stigma*. How many divisions has it? The pistil with its scale is called the *pistillate flower*. Make a drawing of a pistil with its scale. The lower part of the pistil is called the *ovary*. Make a cross section of it. Examine with a lens and draw. The round bodies in it are *ovules*. These will develop into seeds when the eggs in them are fertilized. By what agent is pollination accomplished in the willow?

Examine the stigma with a lens or microscope. Do you see any pollen grains on it? Draw a stigma showing the character of surface and pollen grains if you find any. The stalk on which the stigma is located is called the *style*.

REFERENCE

Densmore, H. D., *General Botany*.

EXERCISE 15

II. SPERMATOPHYTES

2. Angiosperms

f. Flowers (Continued)

The Oak (*Quercus*). Examine carefully branches of white oak with the dangling bodies near the tips. These are called the *inflorescences* or aments. From what years growth do they arise? Do they arise from buds? How many aments arise from each bud? On this year's growth, look for female flowers in axils of leaves. Make a sketch of a whole branch showing male and female flowers. The oak is moneocious.

With a hand lens examine a male flower. Draw it, showing the number of stamens and any accessory parts. Compare with willow. Remove a stamen and draw, showing the number of divisions of the anther.

With a hand lens examine a female flower. Draw it, showing the number of pistils and accessory parts. With a scalpel make a median longitudinal section through the pistil. Determine the number of ovules in each pistil. What kind of fruit does the oak produce?

Examine branches of black oak. Do you find acorns on the last year's branches? When do these mature? How does this oak differ in habit of reproduction from the white oak? Sketch a branch showing one-year old acorns, male flowers, and female flowers.

Examine an acorn; sketch. What does the *cupule* come from? The acorn? Break open an acorn and note contents. Does it have endosperm? Sketch the embryo showing cotyledons, plumule, and radicle. Why is the acorn a fruit instead of a seed?

Make a field study of the oaks. Examine acorns and look for one germinating. Why do not more acorns germinate? If you find one germinating make a sketch of it. Learn the names of as many oaks as you can find and their distinguishing characteristics.

REFERENCE

Densmore, *General Botany*.

EXERCISE 16

II. SPERMATOPHYTES

2. Angiosperms

f. Flowers (Continued)

Cinquefoil (*Potentilla*). Examine the plant. Note form and the relative size of the root, stem, leaves, and flowers. What kind of leaf has this plant? If a flower bud is present show that also.

Make careful drawings of the flower from under and upper views. Split the flower longitudinally and draw it, indicating the relative position of the parts of the flower and the number. Determine the number of *sepals*, *petals*, *pistils*, and *stamens*. Note the arrangement and make a floral diagram of the flower according to diagrams on pages 326, 328 and 329 in Ganong's *Text Book of Botany*.

Remove a sepal and sketch. Is it smooth or hairy? What is this organ for? The sepals taken together make up the *calyx*. Examine a bud and determine the arrangement of sepals in the bud. If they are arranged edge to edge they are valvate; if they are overlapping they are either convolute (spiral) or imbricated in more than one whorl.

Remove a petal and sketch. What is this organ for? The petals taken together make up the *corolla*. The calyx and the corolla make up the *perianth*. Examine a bud; remove the calyx and sketch, showing the arrangement of petals.

Remove a stamen and draw under a lens. How many divisions in the anther? Put some pollen on a slide and examine in transmitted and reflected light. Draw a pollen grain under high power. From prepared slides draw accurately a cross section of an anther.

Remove a pistil and draw under a lens. Is it *simple* or *compound?* Make a section through the ovary and sketch. How many ovules are there in each ovary? What kind of a fruit does this plant produce?

REFERENCE

Robbins, W. W., *Botany of Crop Plants*.

EXERCISE 17

II. SPERMATOPHYTES

2. Angiosperms

f. Flowers (Continued)

May Apple or Mandrake (*Podophyllum*). Observe the habit of the plant. What kind of stem has it? What kind of leaf? Where do the roots arise? What kind of roots has it? Where is the flower located? Make a habit sketch of the plant showing stems, leaves, flowers, and fruit, if any.

Study the flower. Make a habit sketch of it showing as many parts of it as possible. Determine the number of sepals, petals, stamens, and pistils. Remove sepals and petals and sketch one of each. Draw the flower with the perianth removed. Draw an individual stamen under a lens. Put some pollen on a dry slide, examine, and draw. Put some pollen in a drop of water, examine quickly, and draw. What is the difference? What is it due to? Draw a pistil. Make a longitudinal section of the ovary and sketch. Also make a cross-section and draw. Where are the ovules located? The place where the ovules are located is called the *placenta*. What kind of a fruit does this plant produce? How is it pollinated?

Make a diagram of the flower showing the number and position of flower parts including a section of ovary.

Wood Sorrel (*Oxalis*). Examine flowers of this plant as above. Note especially whether the anthers are above or below the stigma. You should find both kinds of flowers. Such flowers are called *dimorphic*. What is the purpose of dimorphism? Note that some flowers are yellow and some violet. This characteristic puts these plants into two species. Study this flower as in may apple. Note whether the ovary is simple or compound. Is the style single or divided? Note the relation between the number of styles and the cells of the ovary.

Draw the fruit. What kind of a fruit does this plant produce? Select a plant with mature fruit. Touch a dry mature fruit. What happens to the seed? How is this phenomenon brought about? What is the purpose of it?

The above flowers are *perfect* and *complete*. Why? From prepared slides make a drawing of a mature pollen grain under high power. How many nuclei do you find in each pollen grain? What are they?

REFERENCE

Densmore, *General Botany*.

EXERCISE 18

II. SPERMATOPHYTES

2. Angiosperms

f. Flowers (Continued)

Vetch *(Vicia).* Examine the flower of vetch. Note that it has an irregular flower. This is called a *zygomorphic flower.* What symmetry has it? Remove the petals carefully, arrange them as they are in the flower, and draw. The middle one is called the *standard;* the two on each side, the *wings;* and the one below, the *keel.* The keel is composed of two fused petals. What kind of calyx does this flower have? Draw the flower after the perianth has been removed. Show in your drawings the number of stamens. Are they all separate or united? Remove stamens and draw the pistil. Is it simple or compound? Draw a fruit. What kind of a fruit has it? Make a cross section of it and draw, showing the number of cells and where the ovules are attached (the placenta). How is pollination brought about in this plant? What kind of a flower has vetch? This flower is characteristic of the plant family called the Leguminosae. Name as many plants as you can which have this kind of flower.

Iris. Study the flower of wild iris (blue flag). This is an example of a flower in which the ovary is below the perianth (epigynous), and the perianth is partly united into a tube. Determine what are the sepals and petals. Where is the stigma? Is it single or divided? Where are the stamens? Draw the whole flower, showing the location of the ovary by dotted lines. Remove sepals and draw one. Draw a flower with the perianth removed. Draw a stamen. Examine tips of a stigma lobe. Note it is split with a lip on the under side. What is this lip for? Examine it with a lens. Do you see pollen grains on it? Explain fully how this plant is pollinated. Make a cross section of the ovary and draw under a lens. How many "cells" has it? How many ovules in each cell? Where are they attached? Is this a monocot or a dicot plant?

Examine some pollen grains on a dry slide and draw. Are the grains small or large; smooth or rough? Drop some pollen

grains in a ten per cent. sugar solution in a petri dish and leave over night. Examine next morning. What has happened? Sketch.

REFERENCE

Robbins, *Botany of Crop Plants;* Densmore, *General Botany.*

EXERCISE 19

II. SPERMATOPHYTES

2. Angiosperms

f. Flowers (Continued)

The Daisy (*Chrysanthemum*). Make a sketch of the plant showing the flowers. Study the "flower". Note the green *involucre*. Is it made of more than one layer of bracts? This is a composite head with two kinds of flowers, the white *ray flowers* and the yellow *disc flowers*. Carefully remove a ray flower. Draw it. This is an epigynous flower. Does it have a calyx? How many petals are there? Are they all separate or united? Is it a perfect flower? Is it "fertile"? About how many ray flowers are there? Do these flowers have bracts at the base? Study the disc flowers. What kind of a flower is this? Remove an open flower and draw under a lens. Does it have bracts and calyx? Remove the corolla. Are the stamens separate or united? Is this flower perfect? What kind of fruit does this plant have?

The Dandelion (*Taraxacum*). Make a sketch of this plant showing a flower cluster. How many kinds of flowers are found in each head? Remove a flower and sketch under a lens. What kind of a flower is this? Of how many petals is the corolla composed? Are the flowers perfect or imperfect? Where is the ovary located in relation to the corolla? Is there a calyx present? This is called *pappus*. Does each flower have a bract? How many stamens are there? Are they separate (distinct) or united? Examine the fruit. Sketch a fruit under a lens. What kind of a fruit is it? What is the circle of hairs at the top of the beak for? What part of the flower does it represent?

These flowers are considered the most advanced. Compare these with the flowers studied previously, beginning with the willow. What is the difference between a primitive and an advanced flower? The composite head is considered the most advanced inflorescence. Compare this inflorescence with the flower clusters studied before. What are the characteristics of an advanced inflorescence?

REFERENCE

Densmore, *General Botany*.

EXERCISE 20

II. SPERMATOPHYTES

2. Angiosperms

g. Embryogeny and seed development

Shepherd's Purse (*Capsella*). Make drawings of *Capsella* with flowers and fruit. Study the flower and note the kind of pistil it has. Draw a fruit separately. Carefully open a fruit. How many partitions (cells) has it? How many rows of ovules in each cell? Where are they attached? What kind of a fruit is it? This plant belongs to the Crucifer or Mustard family. Note how the fruit splits open. This kind of a fruit is called a *silique*.

Study slides of sections of the young ovary of *Capsella*. These are serial sections cut longitudinally and parallel with the flat surfaces. Be sure you understand how the sections are cut and why they are cut this way. Examine a good section under low power and locate the ovules. Make a diagrammatic sketch of a good median section showing where the ovules are attached and divisions of the ovary.

From these slides, make accurate drawings of the development of the embryo from the youngest to the most mature stages. In the younger stages you will have to use high power. What does this embryo come from? Do you see any endosperm? Study a drawing of a mature female gametophyte in Angiosperms. What does the endosperm come from in Angiosperms? In drawing the different stages of the embryo it is better to select first a rather advanced stage. Draw this, including the endosperm and the whole ovule. Then, look for younger stages. Only one stage will be found in one slide. Why? Do not draw the first one you see; search until a perfect embryo is found. It may not be in every section on a slide or on every slide. At least five stages should be drawn.

REFERENCE

Coulter, Barnes and Cowles, *Textbook of Botany*, I.

EXERCISE 21

II. SPERMATOPHYTES

2. Angiosperms

b. Fruits

A fruit is a ripened ovary and its contents and, in some cases, accessory parts. Some fruits (achenes) like corn, wheat, oats, and other grains can hardly be distinguished from seeds. The fact that they are fruits can be shown from their structure and development. Fruits, from an economic standpoint, are ripened ovaries which are more or less fleshy and conspicuous. What is the function of such fruits? Young fruits are usually not palatable or edible. What advantage is this to the plant?

Dry Indehiscent Fruits. You have already studied the grains, so these will be omitted in this exercise. Examine fruits of the following plants: maple, elm, basswood, Tree of Heaven, ash. What is peculiar about these fruits? What is the significance of this peculiarity? How do these fruits differ from achenes? What structure in the grasses peform the same function as the fruit appendages in the above? Draw these fruits. What are some of the other dry indehiscent fruits. How do they differ from the above? How is the function of seed distribution taken care of in these plants. What are these fruits called?

Dry Dehiscent Fruits. Study fruits of Columbine, vetch, and mustard. How do these fruits differ from those studied above? Also study and sketch fruits of okra, poppy, and violet. What are these fruits called? How do they differ from those studied above?

Fleshy Fruits. Study the following fleshy fruits: plum, peach, grape, tomato, orange, and persimmon. Make drawings of whole fruit and of sections. How do the first two differ from the others? What are such fruits called? How many carpels make up each fruit? What is the "stone"? How do the last three differ from the first two? What are they called? Study and draw cross and longitudinal sections of the apple and pear and explain the different regions. What is such a fruit called?

Aggregate and Spurious Fruits. Make a thorough study of the following fruits: blackberry, strawberry, mulberry, pine-apple. Make drawings and explain what each part of the fruit stands for and how they are formed.

REFERENCES

Martin, *Botany With Agriculture Applications;* Ganong, *A Textbook of Botany:* Weatherwax, *The Story of the Maize Plant.*

EXERCISE 22

II. SPERMATOPHYTES

2. Angiosperms

i. Seed Dispersal

Seed dispersal is just as important as seed production. In this exercise we are going to study the different methods that plants have of distributing their seeds. It is not possible to study all plants in this vicinity which show peculiar adaptation for seed dispersal, because the fruits are not available at this season. You have already learned something about seed dispersal in connection with the study of seeds and fruits. In the study of this subject, there are two principal things to bear in mind; namely, the nature of specialization and the specific agent involved? In this connection it is also well to recall the methods and agents for pollination. Why do you, in so many cases, see resemblances between the two processes?

Study the following fruits and seeds and make drawings of each type: cotton, milkweed, thistle, *Clematis*, beggars lice, *Desmodium*, *Bidens*, cockle burr, burdock, *Paulownia*, Devil's needle, mullen, sand burr. Specify whether it is a seed or a fruit you are dealing with, what kind of fruit, and the agent or agents involved in each case.

Also make a study of the following: *Oxalis* (wood sorrel), stork's bill, bitter cress (*Cardamine*), touch-me-not, squirting cucumber (the last two may be omitted if material is not available), and geranium.

In your notes, include a classification of the different methods of seed dispersal and cite examples in each class. Also include a discussion of other plants not mentioned above and the economic importance of this specialization.

REFERENCES

Martin, *Botany With Agricultural Applications;* Bower, F. O., *The Living Plant;* Strassburger, *Textbook of Botany* (5th Ed.); Coulter, Barnes and Cowles, *Textbook of Botany*, II.

EXERCISE 23

II. SPERMATOPHYTES

3. Classification and Identification

Obtain several flowering plants from your instructor and a copy of Gray's *Manual*. Study the plant carefully and determine the following points: presence or absence of parts of flower, parts distinct or united, number of parts, relation of stamens to petals, kind of pistil, kind of ovary (simple or compound, number of compartments, or "cells"). To determine the last, it is necessary to make a thin cross section of the ovary.

Next, open the manual at the front and look for the place where it says "Spermatophytes". If your plant is a flowering plant it belongs of course to the "Angiosperms". Then, determine whether it is a monocotyledon or dicotyledon. This may be determined from the number of sepals and petals and the veinings of the leaves. From here on the key is self explanatory. Should you find any term which you do not understand, look it up in the glossary in the back part of the book.

What is *Taxonomy?* What relation does it have to identification? Where does this subject stand in the history of botany? Why? Why is it necessary to have it to-day? What is the "Binomial Nomenclature"? How is it usually written? What are the advantages of a "scientific name"? What are the advantages of a "common name"?

After each category below write the name of the division to which each plant you have identified belongs:

Kingdom
  Division
    Class
      Order
        Family
          Tribe
            Genus
              Species

REFERENCES

Gray, A., *Manual of Botany;* Small, J. K., *Flora of Southeastern United States.*

EXERCISE 24

III. FIELD STUDY

Plants in the Early Spring. Start with the same mental attitude that you should have started out with in the autumn and with the same equipment. Notice how the plants differ from those in the autumn. Which plants have leaves on them, which have none? What plants are flowering? What plants are flowering before the leaves come out? How could you identify a plant in this season? What fruits do you find? What herbs? How have these herbs survived the winter? What is a rosette plant? Which did you find? Where do plants begin to grow first in the spring? What kind of plants are vernal flowers? What advantage is there in flowering early?

Study also the relation of plants to habitat. Which plants grow on uplands? Which grow on lowlands? Which in and near the water?

Write a paper on this field trip. Include answers to the above questions, and add anything else you have learned by your observation.

EXERCISE 25

III. FIELD STUDY

Plants in the Late Spring. Bear in mind what you have seen on previous trips and compare it with what you see on this one. For example, what trees, shrubs, etc., blossom in the spring with the coming of the leaves? Which blossom after? Study the plants from the standpoint of whether they are annuals, biennials, or perennials. Learn the names of all plants you see. Study the flowers you find and classify them. How many weeds do you find? To what family of plants do most of them belong? Are they native (*indigenous*) or foreign (*exotic*). What is a weed? What plants are in fruit at this season? What are winter annuals? Name one or two. If possible study insect pollination. Write a well organized paper on what you have observed and the value of field work.